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

Lindsay Hetherington[1], Kerry Chappell[1], Hermione Ruck Keene[1], Heather Wren[1], Mutlu Cukurova[2], Charlotte Hathaway[1], Sofoklis Sotiriou[3], Franz Bogner[4].

[1]*Graduate School of Education, University of Exeter, Exeter, UK*

[2]*Institute of Education, University College London, UK.*

[3]*Ellinogermaniki Agogi, Athens, Greece*

[4]*Department of Biology Education, University of Bayreuth, Bayreuth, Germany*

Corresponding Author: Dr Lindsay Hetherington, Graduate School of Education, University of Exeter, St Luke's Campus, Heavitree Road, Exeter, EX1 2LU, UK. Email: L.Hetherington@exeter.ac.uk

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Abstract

Background*:* Creativity across all disciplines is increasingly viewed as a fundamental educational capability. Science can play a potentially important role in the nurturing of creativity. Research also suggests that creative pedagogy, including interdisciplinary teaching with Science and the Arts, can engage students with science. Previous studies into teachers' attitudes to the relationship between science and creativity have been largely situated within national educational contexts.

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

Sample and Methods: 270 educators, broadly defined to include primary (age 4-11) and secondary (age 11-18) teachers and trainee teachers, informal educators and teacher educators, responded to a survey designed to explore perceptions of the relationship between science and creativity. Respondents were a convenience sample recruited by project partners and through online media. The elements of the survey reported here included Likert-scale questions, open response questions, and ranking questions in the form of an electronic self-administered questionnaire. 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: The findings show broad agreement internationally and across phases that science is a creative endeavour, with a small number of educators disagreeing about the relationship between science and creativity in the context of school science. Those who disagreed were usually secondary science teachers, from England, Malta or outside Europe (primarily from the United States). The role of scientific knowledge within creativity in science education was found to be contentious.

Conclusions: That educators broadly see science as creative is unsurprising, but initial exploration of educators' perspectives internationally shows some areas of difference. These were especially apparent for educators working in formal education, particularly relating to the role of knowledge with respect to creativity in science. With current interest in STEAM education, further investigation to understand potential mediating factors of national educational contexts on teachers' perspectives 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 the perspectives of a range of stakeholders from the UK; EU; USA; Canada; North Africa and Australia on the relationship between creativity and science education. We are focusing on perspectives, rather than beliefs, because the concept of teacher 'beliefs' is multifaceted and messy (Pajares, 1992), involving cognitive, affective and episodic dimensions. Examining teacher's 'perspectives' while acknowledging the multidimensional nature of beliefs, involves a tighter focus on the way in which teachers perceive concepts, situations and events. Beliefs act as a filter in shaping the perspectives (Fives and Buehl, 2012). Thus, our study focuses on teacher perspectives on the concept creativity in science education, offering an opportunity for comparison across primary, secondary and informal settings and those involved in teacher education, as well as exploring similarities and differences between educators working in different 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 often viewed as a fundamental 21st Century educational capability, evidenced by its planned inclusion in the 2021 PISA test (OECD, 2015). 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), and claim that teaching for scientific creativity is 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. The TIMSS/PIRLS data (Mullis et al., 2016) shows that comparison of the curriculum context and the extent to which pupils are taught by specialist teachers suggests that whilst the core scientific content is similar in many of the countries from which the sample in our study was drawn, there are some key differences. For example, in Sweden, there was a shift in 2011 to a more content-specified curriculum, yet the relationship of science to society remains more strongly emphasised than, for example, in the German region of North-Rhine-Westphalia. In Serbia, curriculum is strongly centrally driven compared with the multiliplicity of curricula in Germany across different regions and types of school. In Norway, the curriculum is structured around key skills that are taught in all subjects such as oral skills, numeracy and literacy: science is structured by core areas with a strong focus on scientific methods in 'the budding researcher' aspect. Similarly, differences can be easily discerned in terms of access to technology, access to specialist laboratories, use of text books, and the age at which pupils begin to be taught by subject specialist teachers (Mullis et. al, 2016). 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. Despite the fact that creativity is widely recognised as important to promote in schools, its does not always occupy a clearly stated position within school curricula. For example, in England, creativity as a cross-curricular feature of the national curriculum has 'waxed and waned' and it is argued that teachers focus less on teaching for creativity within and across subjects because of the challenges of assessing the impact of their teaching on pupils' creativity (Lucas, Claxton & Spencer, 2013). As well as the positioning of creativity within the curriculum, it is apparent within some research that teachers themselves tend to hold beliefs about creativity that align it strongly with art and, "even where teachers acknowledge that creativity could be manifested in any domain, they tended to limit creative thinking to literary and artistic tasks rather than identifying creative thinking in a particular domain" (Andiliou and Murphy, 2010, 215). This suggests that for some teachers and policy makers, science may not be viewed as an inherently creative subject. We argue that it is important for educators to recognise the role of creativity in science to help pupils develop their creative thinking across subjects.

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', to be used across national contexts to foster engagement in science and the development of students' creativity.

We developed a survey with both quantitative and qualitative items. Through exploratory factor analysis, we developed a combined scale to explore attitudes to creativity in science. Qualitative data were explored thematically and synthesised with the quantitative findings to add depth and richness. Our findings suggest that there is broad agreement from our respondents that there is a relationship between science and creativity: science is seen as a creative endeavour. However, some differences were apparent in perspectives on the relationship between scientific knowledge and scientific creativity. The relationship between perspectives on 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 before explaining the development of the instrument used and analytical approach to quantitative and qualitative elements. We present the findings and explore international educators' perspectives in relation to three key themes driven by our research questions and subsequent analysis: 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. This study, which is distinctive in looking at educators' beliefs across a broad range of national contexts, therefore 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 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, feeling, and involvement in real challenges (Treffinger, Isaksen and Firestein, 1983, cited in Fasko 2001, 319) is linked to motivation and 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': when 'what if' and 'as if' questions are posed, answering them is 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) and developed within creative science pedagogies (Chappell *et al.*, forthcoming in 2019) 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). These features are taken up within the creations project with respect to a range of ways of looking at creativity in education: they offer guidance in terms of 'teaching for creativity', they enable 'creativity in learning' to be facilitated and identified, and they act as a guide to engendering 'creativity in the classroom' (Frodsham, 2017). They are not, however, largely focused on 'creative teaching' as opposed to 'teaching for creativity' (Jeffery and Craft, 2004), since the project focuses primarily on developing creativity in students.

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 agreement within the literature about the creative nature of science, although there is often a mismatch between researchers' and teachers' beliefs in this respect (Andiliou and Murphy, 2010). As a result, 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 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, creativity within science is linked to the processes of scientific inquiry (Garrett, 1987). Furthermore, Rocard et al. (2007) note that because curiosity, investigation and questioning are 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, multiple studies have explored inquiry-based science education as an approach to teaching for creativity in and through science. For example, Barrow (2010) argues that using problem solving in science education helps increases motivation and enhances the creative process, promoting learning. Furthermore, a literature review of creativity in the early years (Cremin et al. 2015) revealed connections between IBSE and creativity: where IBSE and creativity intersect via exploration of ideas through experimentation, dialogue, questioning and evaluation, 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 taught with Inquiry Based Science Education, it is important that teachers have a clear understanding. 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,there are challenges in translating this relationship into practice. 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 project work.

The studies discussed above 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 potential 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.

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?
- How do international educators' perspectives on the inclusion of opportunities for creativity in science education differ?

With respect to each of these questions, we additionally sought to find out if there are differences in perspectives across phases/roles/national contexts? We designed a survey to seek the views of educators internationally 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 used as it could be distributed to, and self-administered by a wide range of international participants in a short time frame. We were not able to access a representative sample of educators from each country and acknowledge that respondents are likely to be those with an interest in creativity in science education, or more generally engaged in professional discourse about education. Our work is situated within a broader interpretive study and quantitative methods and statistical analysis are not used inferentially, but to describe the views of educators who engaged with us to raise questions about the role and status of creativity in science education.

In addition to data collected through the survey, a further small source of opportunistic data was drawn from tweets on the subject of 'the relationship between creativity and science', opportunistically collected through an informal online chat on this topic 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. This additional source of qualitative data was used to supplement the questionnaire. Twitter is a public platform and therefore comments published there are in the public domain. All those involved were made aware that this was a chat hosted as part of a research project. Participants in the chat were invited to refuse permission for their comments to be analysed as part of the research: none did so. 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 qualitative data drawn from open-ended survey questions. Participants in the chat were drawn from the professional science education community whose stated roles were informal science educators, science teachers, and science teacher educators. This data was only used in the overall analysis describing general perspectives, rather contributing to the analysis of perspectives by role, age-range taught, or national context, as these could not be confirmed in the 'chat' context. They were analysed separately from the questionnaire data and drawn in to the analysis in its final stage. This additional opportunistic data collection complemented the more structured survey by providing a very open and unconstrained opportunity for interested participants to comment on the relationship between creativity and science.

Ethical approval was sought in line with the lead author's institutional 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. Ethical approval was received in advance of data collection. Questionnaire participants were required to agree that they had read information about the project and how their anonymised data would be used, stored and reported before proceeding to complete the survey. Twitter participants were reminded that the hosting of the chat was part of a research study before the hour long 'chat' began. Publishing a tweet is equivalent to putting opinion in the public domain: nevertheless, participants were reminded of the nature of the research study at the end of the chat, and invited to complete the survey. In reporting the survey and online chat no respondent is identified. The survey was live from 1st – 29th February 2016, the online chat took place on 15th February 2016 for one hour.

Development of the Instrument

The survey instrument was developed with reference to the findings of previous studies exploring 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 framework (Chappell et al., 2015). The survey used a branching structure to allow participants with different backgrounds to answer questions relevant to them. A combination of Likert type questions and ranking questions were used to yield quantitative data to describe and compare the perspectives of different groups of educators. The open-ended qualitative questions allowed themes to emerge that may not have been anticipated in advance. Table 1 shows the focus of different questions and the nature of respondents for each section. In this paper, we report on sections 2 and 3. The remaining sections focused on teacher development and are described in the Creations project deliverable D2.4 (Hetherington et al., 2016).

TABLE 1

Section	Respondent Type
Background Information	All
Perspectives on creativity in science education (Quantitative)	All
The relationship between Science and Creativity (Qualitative)	Primary and Secondary Teachers or Trainee Teachers and Informal Science Educators

Perspectives about Teacher Education	Teacher Educators
Teacher Education and Professional Development	Primary and Secondary Teachers or Trainee Teachers, Informal Educators
Experiences related to Creations Project Features	All

The LimeSurvey™ tool was used for questionnaire design, online hosting and data capture in order to have a secure survey portal hosted by the corresponding author's home institution. For data triangulation, illumination of themes and statistical data analysis, the survey included a variety of question types: Likert-type rating scales; ranking statements in order of importance; and open questions (Fowler, 2009). Next, we outline the development and validity of the survey sections presented here.

Devising the questions on the esurvey

Section 2 was made up of two elements: 1) Ten five-point Likert scale statements about the relationship between creativity and science, and 2) nine statements about the purpose of science education for ranking. Likert statements were chosen to reveal educators' perspectives about science and creativity because the use of a scale allows respondents to 'shade' their responses rather than give a straightforward either/or response. It also allows the researchers to analyse the data either as a whole, individually or through sub-scales as well as comparing the data for different groups. With respect to respondents' purposes for science education, where a Likert scale could enable all purposes to be deemed 'highly important', ranking statements ensure a more finely grained insight as the respondent is required to choose the relative importance of each statement.

The Likert scale items composed 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’) 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’). 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 (to check that they are relevant to, and likely to be effective in answering, the research questions) by science educators from Germany, Greece and the UK.

Since the literature suggests that teachers do not always see creativity as something to be taught and learned in the context of science (Andiliou and Murphy, 2010), our second research question about educators’ purposes for science education was important. We wished to understand how educators’ located creativity in their purpose for teaching and learning science. To gain insight into educators’ ideas about the purpose of science education, a set of 9 statements were developed, with respondents asked to place them in rank order of importance. Statements included 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 such as contextualised, inquiry-based pedagogies that are often open-ended, student-oriented, exploratory and group-based and thus related to IBSE, 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 in the UK 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.

In Section 3, respondents were 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.

Participants

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 the EU’s Scientix. Although any interested party could respond to the survey, the survey requested information about the roles and experience in education and we were therefore able to ensure that the respondents whose data was used were science educators, as required by our research questions. Through these means, 270 respondents completed the questionnaire, with an additional 10 participants in the qualitative analysis drawn from the twitterchat.

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. Therefore the viewpoints of the more experienced educators are also from formal settings where the considerations of curriculum are perhaps more to the fore. 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% held 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.

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, in which responses with missing data in section 2 were removed, a principal axis factor analysis was conducted on the Likert-scale 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 this 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. The analysis suggested the removal of the item 'creativity in science is individual' from both of the factors extracted, leaving one factor composed of items relating science and creativity, and one 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. Figure 1 shows the items in this scale. Testing for reliability of this scale suggests it is reliable (Cronbach's alpha = 0.822). The items extracted in the second factor were limited to two items that do not form a reliable scale (Cronbach's alpha = 0.414) and were thus analysed individually.

FIGURE 1: The ‘Science is Creative’ scale, extracted through exploratory factor analysis.

Science is Creative
Science requires you to use your imagination
There is a place for creativity in scientific method
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

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).

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. To explore differences in perspective about the relationship between science and creativity using the combined 'science is creative' scale, a mean response to all items within the 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 indicative of strong disagreement, was calculated for each respondent. Descriptive statistics such as mean and standard deviation for the whole scale (by country, respondent role, or other identifying characteristic) could then be explored. Mean responses across the combined 'science is creative' scale, showed a strongly positive stance internationally, ranging from 4.09 (Malta) to 4.49 (Greece). Responses by country are shown in table 2.

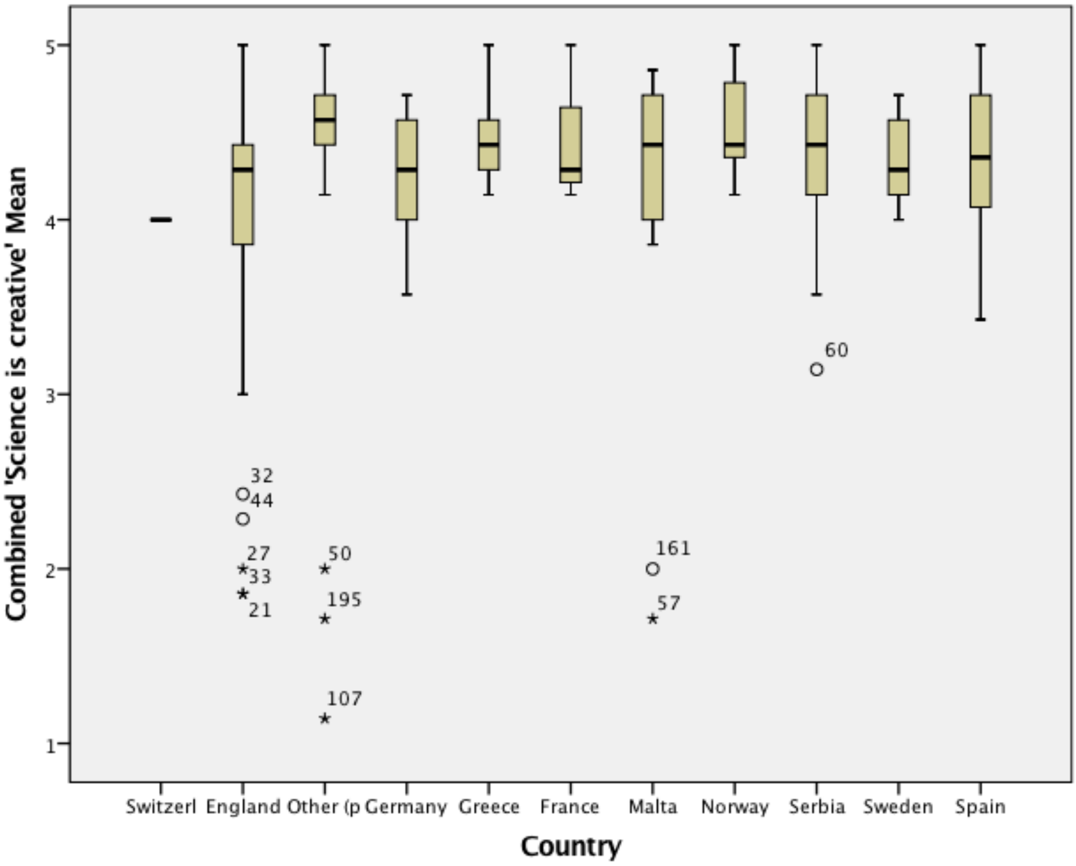
TABLE 2. Responses to the 'science is creative' scale by country. Sample size, mean and standard deviation for the scale as a whole are shown for each country, where 0 is strongly negative and 5 is strongly positive.

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

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). 2shows 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 (central line within the box), interquartile range (IQR) (box), and maximum and minimum (whiskers). Where the data has a very large spread, the whiskers show 1.5*Interquartile Range (which defines a step), with the remaining cases shown as outliers (circles and stars showing 'out' and 'far out' outliers respectively, defined as 1 and 2 steps beyond 1.5*IQR). 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 2: 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 educators' 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 3 shows themes with associated codes, with indicative quotes in italics provided where it is useful to expand or explain the code or theme.

Table 3 – Thematic analysis of open statements about the relationship between scientific inquiry and creativity.

Theme	Codes within theme
The intrinsically creative	Question Posing

nature of scientific inquiry *I think scientific inquiry is by its nature creative*	*Posing appropriate questions is a creative act* Problem Solving *Scientific method isn't especially creative, but solving problems to apply it can be*
The nature of creativity	Thinking differently *Unless there is some outside the box thinking…science simply becomes a reiteration of previous theories* Connection of creativity to innovation. *Creativity connects to inquiry in the development of new ideas* Link between creativity and imagination *In order to state hypotheses you need pre-imagined results* Making connections between ideas *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. *Creativity [in school] can be actively distracting [pupils] from acquiring the factual and method knowledge needed to pass exams.* The potential of creativity to support autonomy and ownership over learning. *Allowing children to develop their creativity in science encourages them to explore concepts* Creativity might arise from the application of new knowledge gained from an investigation process. *Applying what you learn from investigation can be very creative, for example in engineering.*

Qualitative data suggests that for most of these themes, there was broad agreement between educators, 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 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 educators 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 educators 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 educators 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 learning of scientific knowledge and did not tend to see science as creative. Some educators who broadly agreed with the statements in the 'scientific creativity sub-scale' *also* agreed that prior knowledge was necessary for students' questioning, suggesting that for some educators, knowledge and scientific creativity are linked. This finding suggests that educators' conceptualisation of the role and value of scientific knowledge and creativity per se, and the relationship between scientific knowledge and creativity in question-posing, is not 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 perspectives 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, there was not a general pattern of rationale in the response of secondary teachers who broadly disagreed with statements relating to science and creativity. Their comments and profiles do 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 creativity in 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 originality had a role in science education. 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

As stated above, since the literature suggests that teachers do not always see creativity as something to be taught and learned in the context of science (Andiliou and Murphy, 2010), our second research question about educators' purposes for science education was important. We wished to understand how our international educator respondents located creativity in their sense of purpose for teaching and learning science. 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 4 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 4: 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

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.

Figure 3 shows the relative importance placed on statements of the purpose of science education by country, with rankings combined into ‘high’, ‘middle’ and ‘low’, where ‘high’ is the percentage sum of ranks 1, 2 and 3, ‘middle’ is the percentage sum of ranks 4, 5 and 6, and 'low' is the percentage sum of ranks 7, 8 and 9. Despite the low number of responses from some countries (results should be interpreted with care), numbers were converted to percentages for the purposes of comparison. Statistical tests were not used to explore differences in detail due to low sample size from some countries.

FIGURE 3 – Comparison of & ranking of statements of purpose of school science, combined into 'high, middle and low' rankings.

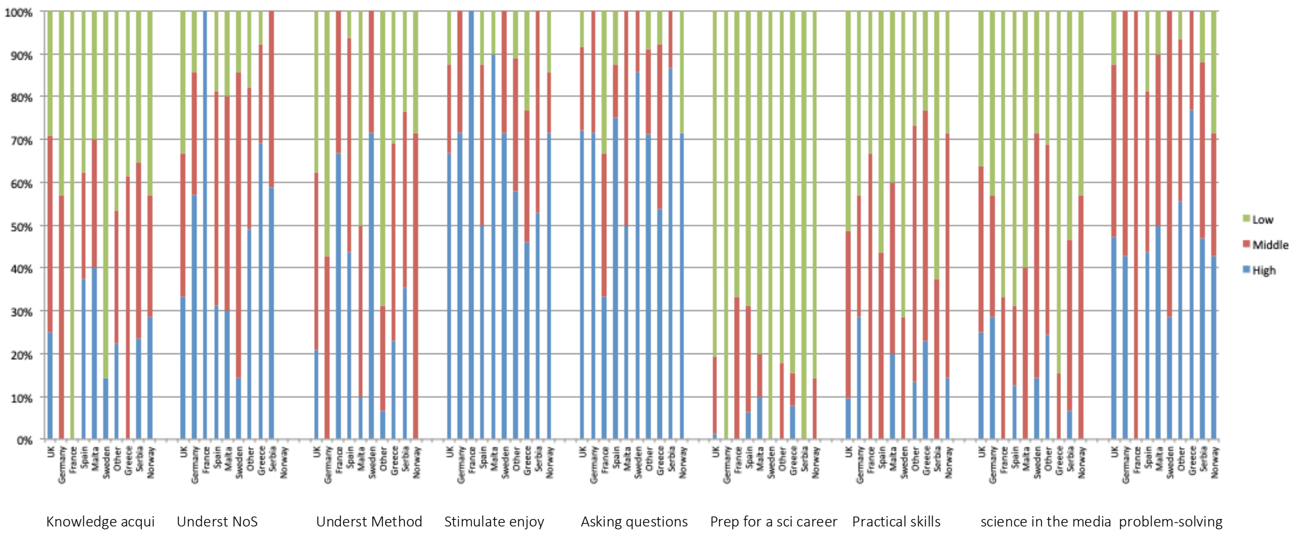


Figure 3 shows the overall perspective described in table 4, with relatively high importance placed on stimulating young people's interest in science, and in question posing and problem solving, along with relatively low importance placed on preparation for a career in science, the development of science practical skills, and the ability to interpret science in the media. Of most interest in terms of international comparison is in relation to the acquisition of knowledge, understanding the nature of science, understanding scientific method, and being able to solve real-world problems. For the latter, responses from Greece showed a particular emphasis placed on problem-solving in comparison with other countries. In Greece and Germany, acquisition of knowledge held less priority than for other countries, whereas it was relatively highly prized in Spain and Malta. Interestingly, given our findings elsewhere in the survey, only 22% of UK respondents ranked the acquisition of knowledge as a high priority. Further study to explore what relationship, if any, can be found between approaches to curriculum and pedagogy internationally with these perspectives on the relative importance of different aspects of science education, and how they are related to creativity, would allow further exploration and interpretation of this initial elicitation of differences in perspective.

Discussion

This study focused on exploration of international educators' perspectives on science and creativity, with respect to the research questions: 1) What are international educators' perspectives on the nature of the relationship between science and creativity, in the context of science education, and 2) How do international educators' perspectives on the inclusion of opportunities for creativity in science education differ? With respect to the first of these questions, the findings in this study indicate that in a self-reporting survey of voluntary respondents across a range of countries, largely drawn from Europe and North America, there is a consensus amongst educators 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 some prior work exploring this relationship in studies about science teachers' conceptions of creativity as well as expert opinion about the nature of scientific creativity (Davies and McGregor, 2017; Frodsham, 2017). However, it is in tension with the suggestion elsewhere in the literature that creativity is more usually associated with the arts than the sciences, with the resulting inference that many educators may not see science as creative (Andiliou and Murphy, 2010). Our findings do also suggest that the role of the scientific knowledge with respect to creativity in science is an aspect about which there is some difference of opinion, which is more apparent, in our study, in England and Malta, and beyond Europe, than elsewhere in Europe. In part, this reflects a sense of domain-specificity with respect to creativity in science: the idea that creativity in science is different to creativity within other subject disciplines. In science, our findings appear to suggest that the scientific knowledge base is deemed particularly important with respect to scientific inquiry and the scientific method, which is where teacher typically locate creativity in science. In other words, the role of scientific knowledge in students' question posing, allowing them to ask their own relevant questions rooted in their disciplinary knowledge, is essential to scientific creativity. Similarly, creativity is domain-specific in terms of students using their knowledge for finding innovative solutions to scientific problems, and applying their knowledge to new contexts and evaluating their findings (Baer, 2012; Feldhusen, 2002).

However, our findings indicate 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 educators 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. However, the nuances of the differences of opinion here, may depend on whether they are formal or informal educators. 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 the nature of scientific inquiry within curricula in each country, although more work needs to be done to explore the 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). This study 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, both in terms of how students deploy disciplinary knowledge in creative learning, and how teachers use disciplinary knowledge and contexts in order to teach for creativity. Reported elsewhere, project findings have begun to explore some of these issues (Conradty and Bogner, submitted; Buck, Sotiriou, and Bogner, 2018).

In relation to our second research question, again our study revealed some broad similarities in perspectives about the relative importance of different aspects of the purpose of science education, some of which relate to scientific creativity as defined and discussed above. For example, question-posing and problem-solving (which relate to creativity) were in general ranked relatively highly and preparation for a career in science usually ranked rather low, with some variability in perspective internationally with respect to knowledge-acquisition, the nature of science, and understanding scientific method. Care must be taken in interpreting the findings for some countries in the sample from which the number of respondents were relatively low (e.g. Spain and France). We believe that it would merit further study to explore the relationship between these perspectives and the national contexts, in particular in relation to differences in curriculum and pedagogy. This might help us confirm and explain, for example, why for Germany and Greece, the acquisition of scientific knowledge is ranked relatively low in comparison to understanding the nature of science and the development of practical skills; whereas other countries appear to place greater relative priority on knowledge.

Conclusion

Our findings highlight the strong consensus internationally (at least according to self-reported perspectives from the voluntary respondents in this study) 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 educators' perceptions of 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 such as art and science interact in relation to both knowledge and creativity when brought together in interdisciplinary creative pedagogies.

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