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Epistemic insights : Contemplating tensions between policy influences and creativity in school science.

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Abstract
Creativity and the way it could be supported in schools is understood differently by policy makers, practitioners and scientists. This paper reviews with a chronological lens the development of policies that include teaching creativity and teaching for creativity. The epistemic tensions between the intentions of Government and the nature of creativity as it emerges in learning or scientific work is introduced and reflected upon. There have been more than nine key educational policies that have been introduced over the last 50 years. Each of these are considered in this paper and related to the ways that creativity is understood and expected to be taught, supported or enacted in schools by policy makers. In the light of the need to support creativity as a key 21st century skill, to ultimately enable current students (who will become the next generation of scientists) to develop the capabilities to address global concerns, this paper highlights issues related to this issue. Epistemic insights are offered that relate to development of aspects of creativity including questioning, developing alternate ideas, 'seeing' things differently, innovation, curiosity, problem solving and evaluating. The ways that policy related to creativity in science appears not to recognise how creativity can be reified in these ways in schools suggests the need for rapid review, especially in light of the up-coming international creativity tests (OECD 2018) in 2021.

Introduction

Success in professional and personal lives has become synonymous with creativity (Glăveanu 2018). He argues this because creativity is typically understood to be the generation of original *and* useful products (Runco & Jaeger 2012). The need to promote this kind of innovation amongst UK scientists has been recognised by the Confederation of British Industry (CBI, 2015) who highlighted the urgent need to nurture aspiring scientists who are currently in schools (as primary and secondary students). Their report suggested that a step-change in teaching was needed to make science 'exciting, interesting and challenging' (ibid : 9) and develop skills of 'reasoning, analysis and curiosity'. The pedagogic focus including developing creativity to make science more engaging and thought provoking, as well as nurturing pupils to become more inquisitive, was intended to increase the number of current students wishing to become scientists. These future scientists would subsequently innovate and contribute to, and even collectively address the on-going demands and necessities of future social and global issues, as highlighted by the Organisation for Economic and Co-Operative Development (OECD, 2015). Despite the desire to nurture creativity, originality and innovation, however, neither the CBI nor the OECD adequately describe how education in classrooms might be reformed to nurture future eminent scientists. Additionally, with 21st century creative skills at the forefront of global initiatives the Programme for International Student Assessment (PISA) has announced the planned inclusion of creativity into the PISA test in 2021 (OECD, 2018). In spite of the international pronouncements, the epistemological nature of creativity to be nurtured in schools has not been clarified and is still a 'contested space' (Colucci-Grey et al 2017). Alongside this concern it has been voiced that international testing of creativity will produce a narrow vision of skills, a widespread standardisation of a multifaceted concept, and market-driven accountability (Guror, 2016). This could have a deficit effect on the global economy and societal culture that is counter to the CBI and OECD's objectives. To this end the aim of this paper is to consider how (or if) UK governmental policies (relating to school education) have recognised the potential to nurture creativity and indeed paid sufficient attention to guide and steer what is required to address future globalised challenges from a pedagogic and learning perspective.

A brief introduction to views of creativity in (science) education

Before considering the ways that scientific creativeness has been recognised and (perhaps) influenced through educative policies a brief introduction is offered here. It was during a keynote speech at the American Psychological Association that Guilford (1950 : 445) first acknowledged 'the neglect of the study creativity'. He also highlighted how there was an unfortunate prevailing attitude that intelligence was bound up with creativity, but he emphasized how almost anyone possessed the potential to engage in 'creative acts' (ibid : 446). Whilst Guilford's address was well received by his peers it was not until 1999 that creativity was nationally recognised as an essential component of the UK curriculum for primary and secondary education. The National Advisory Committee on Creative and Cultural Education (NACCCE) suggested that creativity should be defined as '[an i]maginative activity fashioned so as to produce outcomes that are both original and of value' (NACCCE, 1999:30). NACCCE claimed that creativity could be 'taught' and that teachers needed to 'provide particular conditions' in which it could be realised'. Within a science context, the report identified how, the 'National Curriculum does not support approaches which see science as a creative and imaginative activity' (ibid : 184), but that there was potential for young people to challenge or extend what is known. The NACCCE in their seminal 1999 report 'All Our Futures' endorsed teaching approaches which would influence and develop creativity. They referred to practice that adopted creative methods as 'creative teaching'. They also recognised teaching *for* creativity (NACCCE 1999:102-103), but the lack of clarity surrounding the nature of creativity in science classrooms has since led to many authors exploring what it might look like (Glăveanu 2018). Author (2015) presented eight descriptions of creative thinking and considered how each had contributed to the discussion surrounding innovation and originality in science education. The relationship between process and outcome has been further considered in science contexts, to include '…the formation of all possibilities', alternate perspectives and 'fresh concepts that are original and useful to their creator' (Author 2017). Although original ways of communicating about science through poetry, drama or painting (NACCCE 1999 : 184) were recognised, only fairly recently has the opportunity for the development of creativity in investigational school science been widely acknowledged (Crawford 2007; 2014). Dewey's (1910: 127) proclamation that "when our schools truly become laboratories of knowledge-making, not mills fitted out with information-hoppers, there will no longer be need to discuss the place of science in education" is indicative of the length of time it has taken for science education to recognise and develop opportunities for learners to demonstrate their capability in scientific inquires. Although NACCCE introduced the pedagogical nuance of teaching creatively (TC) and teaching for creativity (T4C), Authors (2017) have more recently reconsidered and redefined these two positions. They describe how TC focuses on '… the teacher and [their]… ability to communicate science in as creative way as possible' and T4C focuses on '…the creativity of the learners and [the teacher's]… role is to teach in such a way as to enable the children to express and develop their creativity'. TC is therefore a pedagogical approach adopting creative materials and approaches to imaginatively communicate about science, which may involve the teachers dressing-up and acting in-role; presenting spectacular scientific demonstrations or adopting games (Authors 2018). T4C is a pedagogical approach that is more focused on ways of supporting students to be creative, original (and agentive) themselves. Examples of creativity emerging in learning, through a T4C approach includes asking open questions and celebrating plausible and reasoned inventive or imaginative ideas. In addition to these two pedagogical approaches, Glăveanu (2018) has recently suggested three ontological ways of considering creativity. They are, i. associating creativity with the arts and emphasizing self-expression, originality, and divergent thinking, ii. connecting creativity with scientific discovery and problem solving and finally, iii. post-modernity creativity which invites the individual to reconsider the everyday from varying (and new) perspectives (ibid). This trilateral division arguably differentiates between the creativities involved in two disciplines (science and the arts) and envisages everyday creativity as distinct. These can be considered alongside Kaufmann and Beghetto's (2009) four types of creativity. They suggest how *mini-c* is everyday problem solving (e.g. the creativity involved in a child trying to solve how to put the correct shoe on their right or left foot or pack away the toys in an already over-full box), *little-c* is related to working out solutions to more theoretical 'what if' problems, *Pro-c* is the creativity associated with acts of innovation or professionals demonstrating how they are original (e.g. qualified scientists) and *Big-C* is about bringing about a significant change within a specific domain, like Darwin and his theory of evolution or Einstein and his theory about relativity. Reflecting on an encounter in school (Author 2017) recounts how a four-year-old girl explained an observation she made. She enthusiastically justified that a spider sat in the centre of a web had done so because a small red berry, positioned slightly to the left of the arachnid's net, was its food source and that the spider was there because it [the food] was positioned close by and was 'easy to get to'. The child did not relate to the presence of the web as a net, spun by the spider to capture small mobile insects. This young pupil eagerly expressed a form of mini-c (her own plausible understanding of the observations she had made), that exemplified Glăveanu's (2018) first view of creative thinking, that of self-expression, originality, and divergent thinking. Re-consideration of a child's plausible alternate to 'see' the everyday from a new perspective demonstrated Glăveanu's third ontological perspective of creativity (Author 2017). A child construing a view from observed phenomena that did not conform to a trained scientist's perspective (their Pro-C) is an example of everyday creativity in the school environment which is in tension with the scientifically accepted explanation of a spider's presence by its web awaiting entangled helpless insects (Glăveanu's second ontological view of creativity). An epistemic insight is offered here, through consideration of the two perspectives, the individual's viewpoint that'…creativity is a new mental combination that is expressed in the world' (Sawyer, 2012:7) and a more sociocultural standpoint where '…creativity is the generation of a product that is judged to be novel and also appropriate, useful, or valuable by a suitable knowledgeable social group' (ibid:8). The young girl articulating her thoughts about the spider and the berry was personally creative. However, judged from a more expert sociocultural position (e.g. assessed from within the enculturated understandings about arachnid behaviour from a member of an academic scientific community) her idea would not be recognised as socially valuable. However, Runco (2003) would suggest that there is '…no incompatibility [between these two stances] if you keep in mind that a personal construction will likely be original and useful to that one individual'. That is, as long as the witness to the individual creativity (the teacher, peer or visiting scientist) appreciates the child's own personalised expression of their reified understanding, this way of recognising the value of each other's epistemological knowledge, according to Fischer and Zigmond (2010) is akin to the way scientists combine their ideas and efforts to advance science. Thus, it is the willingness of the scientists to connect, share their findings and propose fresh collective perspectives that propels development of scientific discoveries arguably illuminating Glăveanu's second way of thinking ontologically about creativity. Who knows whether or not the 'berry' might be attractive to insects who unwittingly become trapped in the spider's web and therefore the plausible explanation of the location of arachnid's presence (and his net) may be more complex than first envisaged.

It is through critically considering the above that we have deliberated upon the following. In education, creativity can be nurtured by a teacher who appreciates (prior experiences and) the child's (or the young scientist's) own ability to develop creative thoughts and ideas, both as an individual and socially with their peers (in a similar fashion to that of collaborating scientists). Individual and community perspectives should also not be considered as mutually exclusive entities in the science classroom when creativity and learning are being reflectively considered. To this end we also argue that both the scientist and pupils learning can be construed through (and encompass) the (past and present) social planes that Craft (2008) labelled middle-c creativity. The middle-c embracing the differing epistemological experiences and/or perspectives that both child and scientist engage in within their communities. Therefore, when it comes to creativity in science education the challenge for teachers would be to provide the opportunities for children to confidently assess the evidence, consider what is salient to them and construe their own unique explanations which may enable them (in the present or future) to generate further original explanations or even solutions to unique real-life problems they face.

Having considered Glăveanu's ways of thinking about creativity and Kaufmann's and Beghetto's four C's, we continue to examine the tensions (or not) of the ways these viewpoints resonate with UK educational curricular policy. This will be done whilst also reflecting upon examples of creativeness, innovation and originality observed in science lessons or by contrasting stories of eminent scientist's work, each appropriate to offer epistemic insights.

Considering Creativity through Educational Policy: Directing creativeness in school science.

Currently the Department of Education (DfE, 2015) states that the purpose behind studying science at school is:

> '[It] provides the foundations for understanding the world through the specific disciplines of biology, chemistry and physics. Science has changed our lives and is vital to the world's future prosperity, and all pupils should be taught essential aspects of the knowledge, methods, processes and uses of science'.

This statement resonates with the prospective (and optimistic) standpoints of both the CBI and OECD. Furthermore, what is also undeniable is that the DfE is inferring that children should be taught both the practical elements of science and scientific theory, but without clear reference to how this relates to nurturing scientific creativity. To offer contextual background to consider how originality in science education is (and has been) directed, through governmental policies, a chronological review of several educational imperatives from 1870 onwards is outlined. Ultimately, this will provide context for further consideration about ways government policy should emphasise, value and promote creativity in science.

Education pre-Plowden (1870-1967)

Victorian Elementary School was, according to Shaw & Shirley (2011), intended to prepare the socially disadvantaged to work in industrialised Britain, rather than to broaden their creative opportunities. Thus, the focus was on reading, writing and arithmetic. Following this, in the early 20th century (pre-second world war), there were three key developments in education. They were: the Balfour Act of 1902 which created Local Education Authorities, the Fisher Act of 1918 which raised the school leaving age to 14, and the Hadow Reports, 1923–31. It was the latter initiatives which recommended there be a transition between primary and secondary school at the age of 11.

In the post war-years the Butler education act offered three types of secondary education (grammar schooling, secondary moderns and technical schools). This was promoted as an opportunity for all children to be educated, despite their societal upbringing. However, it placed the students in schools according to their ability (Coldron et al, 2008) and the selection process still favoured pupils from more affluent backgrounds (ibid). This meant that children from lower social-economic backgrounds were more likely to go to the secondary modern/technical schools which were reportedly unable to meet the individuals growing educational requirements and fulfil their creative potential (Shaw & Shirley 2011).

This falls short of recognising how creativity is not just restricted to the gifted or highly educated. It is evident in all social classes, including those families and individuals classified as poverty stricken and educationally disadvantaged (Alexander, 2010:489). Author (2017) aptly illustrated this when she observed a five-year old girl (who would have been considered to be from a disadvantaged background) displaying her imaginative mind through her written work. Children in a year 2 class were asked to write a few sentences about what an owl would see at night. Most pupils wrote, '…the owl would see some sheep in a field'. However, this young girl went further, she wrote about conversations which took place between the owl and other nocturnal species found in the dark, including, 'the owl said, "hello sheep down below, you look nice and warm in your field" [referring to their fleeces], the sheep replied "Baa!, Yes we are". Whilst where she lived and her parents' employment status may have been seen as a socioeconomic shortcoming by some, it had certainly not hindered this girl's imagination. Yet, the post war educational system would have been set up to place her at a disadvantage to her richer counterparts.

Historical archives also attest to those who do not let their physical, social or economic confinements hinder their creative development. The scientist, George Washington Carver is no exception. Born into slavery in 19th century America he had to toil hard and fight for his education. He eventually became the director of Agricultural Experimentation at Tuskegee University in 1897. Despite this noteworthy appointment he still had to use old pots and pans to create his first laboratory due to a lack of funding (Perry, 2011). His concern for the plight of the southern black agriculturalists drove him to re-appraise cotton plant growing. His keen observations realised how crop rotation could resolve soil nutrient depletion. He also devised countless ways to use plant parts to develop products from dyes to pharmaceuticals. His disadvantaged background meant it was a challenge to prove his scientific abilities and he had to adopt a secret system to retain patency of his methods and formulas. He stated '…after protecting our formulas, I will be glad to show them [the businessmen] everything I know about it' (Washington-Carver as cited in Perry, 2011:35). His practices were arguably born not out of experience within the conventional scientific community but as a pragmatist adopting ways to protect his ingenious techniques from others keen to patent originality. His struggles and success illustrate how (as Guildford claimed earlier) imagination and aspiration should have no social barrier. Boytos et al (2017), suggests that being at a perceived disadvantage (or contemplating how to solve immediate practical problems) can epistemologically nurture the creativity of anyone in a similar underprivileged position to Washington-Carver. Survival and a driving need to succeed can propel individuals to find original, innovative solutions.

History is scattered with scientists who have overcome discrimination and prejudice to become globally recognised scholars (e.g. the palaeontologist Mary Anning and the chemist/physicist Michael Faraday). However, there are those whose socioeconomic backgrounds could be considered more favourable. For example, Edward Jenner, the son of a Berkeley vicar, apprenticed to a local surgeon, aged 14, and formally trained in London. Jenner was a practicing local doctor in a small community and he empathised with the towns' residents (no matter their class status) and cared about their well-being. To this end he responded to a need to be rid of a disfiguring and potentially deadly disease (small pox). He hypothesised that milk maids afflicted with cow pox seemed immune to the small pox disease and set about proving his theory. To accomplish this he applied cow pox fluid to cuts he made on the arms of his gardener's son, James Phipps, and awaited the results. Some days later, after James recovered from the disease, Jenner applied a small pox fluid in the same way. He patiently waited for signs of the disease to manifest but James did not fall foul. Thus Jenner concluded he had successfully made the connection between cow pox and its ability to shield sufferers from small pox (The Jenner Institute, 2016). Whilst, undoubtedly, Jenner's approach to this investigation would be considered unethical in the contemporary western world his commitment to vaccination (a term he coined) would eventually lead to it being valued on a sociocultural level and disseminated worldwide. This brief historical story is recounted to highlight how innovation and originality in science is not class dependent. Additionally, by juxtaposing this account with George Washington-Carver's it becomes possible, with a more optimistic educational outlook, to discern how young aspiring scientists/children (like the young five-year old girl) could become a prominent (possibly internationally recognised) scientist of scientific note in the future.

Returning to the chronological review of UK education and influence on the development of creativity in science, Shaw & Shirley (2011) stated that it was not until the 1960s that the formal class teaching, which was arguably designed to produce a British work force, gave way to new ideas and possibilities in educative practices, such as those expressed in the Plowden report.

The Plowden report (1967)

Whilst a definition of creativity in education was not commonly considered a national priority until 1999, the Plowden report, a decade after Guilford's (1950) address, specifically advocated creativity within the primary school setting (CACE, 1967a; 1967b). It described a practice that placed the child 'at the heart of the educational process' (CACE, 1967a:7) and stressed the need for individual personalised discovery through the environment via 'creative opportunities' (ibid). This report was heavily influenced by Piaget's constructivist theory (Alexander, 2010:90) but this note of recognition that learners were capable of innovative thought did not illuminate clearly the difference between creative teaching and creativity in learning (Authors 2017). To promote individualised discovery (in a radical constructivist sense) it is the pupil who initiates the original thought, suggestion or action rather than responding to the teacher's creative questioning or instructions. Consider this example of agentivity of a year 6 class where exploring how to create a series circuit, the children were given wires, bulbs and batteries and told to work out how to light three bulbs in a series. Ten minutes into this activity a girl was found rubbing a nine volt battery on the carpet. When asked what she was doing she confidently replied, 'The battery is flat. I'm charging it up with static electricity' (Author 2017). Whilst a scientist would consider this child was ontologically incorrect she was nevertheless possibility thinking (Craft *at al* 2007) whilst tackling this everyday problem. She was also drawing on her previous personalised experiences with the scientific phenomenon of ways to increase static electricity. Runco (2003:318) would have linked this type of everyday problem solving to '… the construction of new meaning', through her mini-c, i.e. the girl would/could have eventually discovered (through further experimentation) that batteries could not be fully recharged through increasing their static electricity. All the same, she was, at this juncture, thinking independently, beyond the activity that had been directed by the teacher.

The act of agentively assimilating ideas (correct or not) can be represented through another observation. The science class was focussed on explaining how night and day came to be. A year two girl contemplated the rotation of the Earth, through a visual analogy. The five-year old imagined two people (her friends) swapping places in a room and combined this distinct idea with the Earth's rotation around its axis to physically illustrate the scientific concept of day and night. The child was, however, initially reticent to tell the teacher because she thought the analogy she had formed was 'silly' (her own words). That is, she thought it was an unusual association between two disparate ideas (Author 2017). Interestingly, de Oliveira Xavier et al (2018) believes that teachers only want to present, or discuss, the final results of scientific research to their class, without due consideration to science being socially constructed (often outside the classroom setting). The usual pedagogic expectation of a factually correct scientific answer could explain why the usually timid child was initially reluctant to articulate her original idea. It is the interactive nature of sharing juxtaposed understandings (Bruner 1996 : 56) in learning that was neglected by Piaget's constructivist theory. He reportedly envisaged the child as a 'lone scientist' discovering the world for themselves. It is possible to appreciate, how, from a radical constructivist perspective of that kind individuals can internalise scientifically inaccurate or naive conceptions because they have not been verbally expressed and rendered available for consideration. Personalised theories or understandings can persist well into secondary education. For example, Driver et al (1994) cite two American studies of teenage students, carried out by Sadler (1987) and Baxter (1989), discovered that many pupils did not hold the view that the Earth's rotation on its axis was responsible for day and night. The students, in fact, favoured three different notions. That is, i. the sun moved either around the Earth, ii. the sun moved in an up and down trajectory, or iii. the sun was covered by other planetary objects such as clouds or the moon. Whilst this may seem worryingly inaccurate to some, from a modern scientific perspective, Driver et al (1994) suggested that many concepts held by children are akin to those expressed by eminent scholars from the past. Such as 4th century Greek philosophers Plato and Aristole who composed works describing a geocentric planetary model of the universe (where stars and planets were carried around the Earth). In fact, it was not until the 16th century that Copernicus was credited with the successful model of the heliocentric system (Gingerich, 1985). Thus, fascinatingly the five-year old girl in the story above had contemplated a scientific concept that older pupils and even past historical scholars had misunderstood.

Therefore, if the students are envisaged as learning from their environment and changing 'cognitively' in response to it, even when an activity was initially resourced by the teacher, knowledge then, utilising scientific conventions, would still be left up to the individual child to discover on their own (Driver et al, 1996). Another illustration of this kind of radical constructivism, illustrating how understandings can emerge that differ to that of the teacher (that could be deemed mini-c creativity) is the following observation of two year-six boys engaged in an open-ended task. The boys were provided with two seemingly identical crowns (made from cardboard), but one crown was very slightly heavier than the other. They were given no instructions and a pair of old-fashioned balance scales was placed in front of them. From a scientific stance, the teacher intended that they should have been considering how the fulcrum effected the positioning of the beam when the crowns were positioned (to balance the beam) at either end. However, within approximately twenty seconds of embarking on the task, *they* had discerned that the teacher wanted them to make the crowns weigh the same. They spent the next few minutes having great fun making holes in the cardboard, using the sharp end of their pencils, they thought to adjust the mass of the crowns. Needless to say, whilst they both enjoyed experimenting with the materials the scientific concept to be learned (as determined by the teacher) remained concealed. They left the lesson content, but none the wiser. Therefore, Driver et al's (1996) proposition that invisible concepts of science have to be represented by the teacher somehow was, in this particular case, not unfounded. However, it remains that the boys had innovatively construed an albeit faulty method to adjust the mass of the crowns.

The intentions of the Plowden report to place the learner/pupil at the centre of their own learning appears not to have succeeded. Irrespective of this seminal re-consideration of educational policy, Alexander (2010:91) reported that the majority of schools, during this period, still tended to follow a behaviourist teaching approach which did not incorporate the child's active or personalised creative efforts. Thus, any idea of there being a '…golden age of freedom, creativity, discovery, child-centredness and informality in curriculum learning' during the 60's and 70's appears to be a misrepresentation of what was, in reality, taking place in the majority of school classrooms (ibid:30).

The Education Reform Act (1988)

Even though, during this time period, teachers were reportedly teaching, in the main, in an expositional way, Shaw & Shirley (2011) claimed that they were still the designers and pace-makers of what was being delivered within the classroom setting. Therefore, creative teaching (as later outlined by the NACCCE 1999) could have been practiced. For example, the didactic teacher could illustrate the scientific notion of static electricity in an unusual and fascinating way (by making hair stand on end via the use of a Van de Graaf generator). They could also choose to use an everyday object to enable the children to look at the same science from another angle (such as, using a balloon or ruler to demonstrate the same static electricity effect). Both these teacher-led experiments or demonstrations can be used to pique the children's interest and this would arguably be classified as imaginative, interesting and exciting science in a school lesson. These kinds of teacher-led demonstrations can (and have been observed to) raise exclamations of 'wow!' from a classroom full of 30 pupils (primary or secondary). However, whether the experience generates a desire for the pupils to think further, innovatively or in an original way about science is invariably overlooked.

The autonomy of the teacher-designed approach to schooling was interrupted in 1988 when the government proposed and introduced the National Curriculum (NC) for all pupils aged 5-16 (DES, 1987). This reportedly shifted the control of what was taught (and how) in the classroom from the teachers to the centralised government (Shaw & Shirley, 2011). Alexander (2010:28) claimed that the change was felt necessary at the time because beyond Literacy and numeracy there were reportedly inconsistences in teaching practices and the way lessons were being taught. Shaw & Shirley (2011) believes that this attempt at regulating schooling meant teachers were not able to independently decide what and how to teach their pupils as they saw fit. That is, they were involuntarily becoming deliverers of knowledge content rather than pursuing what they previously might have in a more creative fashion to facilitate learning.

The NC consisted of three core status subjects (Maths, English and Science) and a further seven foundation fields of study. Attainment targets were set for the three core subjects and externally prescribed tests were administered during set years. Schools also had to put into place a continuous assessment system measuring on-going progress. These criteria were set out so that the progress of each and every child could be judged against national standards (Alexander, 2010:32).

However, the NC seemingly had three aspiring aims. That is, i. to provide opportunities for all pupils to learn and achieve, ii. allow every child (no matter their social background) access to a broad curriculum and iii. to promote spiritual, moral, social and cultural development preparing children for life outside of the school environment. Despite this optimistic overtone there was no reference to Plowden's child (or reference to the learner's agentive creativity). The only quoted source that related to personalised learning for pupils, was as a future citizen and simply stated that the introduction of the act was necessary because it '…equips them [the pupil] with the knowledge, skills and understanding that they need for adult life and employment' (DES, 1987:3). Thus, arguably the future education of the British workforce was at the forefront of the then current Government's mind when contemplating the aims of this educational reform act, but creativity, innovation and originality appeared to be overlooked.

National Advisory Committee on Creative and Cultural Education (1999)

By 1998 the then secretary of state and the secretary of state for culture, media and sport, invited Sir Ken Robinson to form the NACCCE. This was, as previously explained, the first report to champion and define creativity in education. In fact, they were promoting an inclusive creative and cultural education, based around both the teacher's practices and the child's developing learning. Thus, unlike the Plowden report the committee had realised (or made explicit) the need for some form of teacher intervention when nurturing creativity.

Alexander (2010:44) defined this commissioned report as '…[i]mportant, visionary and timely'. Yet he also went on to describe it as '…the right report at the wrong time' (ibid). He claimed that it failed to restrain the government's obsession with numeracy and literacy. Robinson (2009) also reported that members of the government ended up referring to the document as the 'arts report' (ibid:257). This emphasis only served to underline how creativity was not associated (by the then Department of Education) with disciplines such as science and maths. This way of thinking, Alexander (2010:240) stated, was reinforced through the government's preoccupation with the 3Rs (i.e. reading, writing and arithmetic). Something that had seemingly not changed since the 1870's.

The Educational Reform Act (1999)

The focus on numeracy and literacy was reinforced within the revised 1999 NC (DfEE and QCA, 1999). Alexander (2010:241) suggested, that this was due to two national strategies (the Literacy Strategy, introduced September 1998, and the Numeracy Strategy, from September 1999). These two policies had apparently taken precedence over any other possible endorsements (including creative teaching). Although, the word creativity was found within the aims of the revised curriculum (DfEE and QCA, 1999:11), and the science programme described how the discipline should enable pupils to think both creatively and critically (ibid:76), there was no further clarity regarding what the DfE meant by these latter two terms and how they related to the pupil or teacher's originality and innovation.

The complementarity of being both critical and creative in science has been acknowledged by many scientists. However, the quotation below highlights the need for criticality to stimulate thinking more creatively. In writing about his work, Ibn Al-Alhaytham, an 11th century scientist (who theorised how a light source could be reflected or refracted, utilising mirrors and lenses before the light entered his own eyes) reputedly notes :

> 'The seeker after truth is not one who studies the writings of the ancients and, following his natural disposition, puts his trust in them…but rather the one who suspects his faith in them and questions what he gathers from them, the one who submits to argument and demonstration and not the sayings of human beings whose nature is fraught with all kinds of imperfection and deficiency. Thus the duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and, applying his mind to the core and margins of its content, attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency.' (Al-Alhaytham cited by Abdelhamid, 2003).

Interestingly, Al-Ahaytham is known for his scrutiny of the then current understandings of how we see objects, such as seeing a lantern hanging from a wall due to light shining out of our eyes. Driver et al (1994) described several research projects where students (from primary and secondary schools) also held these alternative scientific beliefs.

The 'critical examination' that Al-Ahaytham describes in the quotation above starts when a problem has been identified, the solution to which involves consideration of all ideas and possibilities (little-c creativity). Once questions are formulated then the truth seekers (i.e. the scientists) can systematically critique these ideas (and their own reasoned thoughts). The initial critical appraisal, Al-Alhaytham theorised, would enable the current scientific theories to be studied from every perspective before a proposed explanation (or product) could be verified. Notice how Al-Ahaytham's practices resonate with Glăveanu's (2018) three ontological ways of thinking creatively. These features are also arguably akin to the Creative Little Scientist Project's (CLSP) description of creativity. This pan-European research project, described creative innovation as that which is expressed by the child and evidenced in a number of ways, when they '…generate and evaluate ideas and strategies…' (Stylianidou et al, 2014:2) either as individuals or groups that subsequently reason critique them. Valuing individual and collective perspectives envisages the pupils (and teacher) as thinking in similar ways to scientists within their encultured community. Fisher (2001:13) who identified the mutual need for critique to inform creativity characterises this kind of scientific thought as 'critico-creative' thinking.

It is interesting that the critico-creative practices that Al-Alhaytham demonstrated were not explicitly referred to within the main statutory (or non-statutory) requirements of the science curriculum (just in the overall aims). Alexander (2010:238) further highlights curricular tensions when he suggests how 'aims…tend[ed] to head grandly in one direction while the curriculum slink[ed] pragmatically in another'.

The Excellence and Enjoyment strategy (2003)

The 'Excellence and Enjoyment strategy for primary schools' (DfE, 2003) was published because the government had become reportedly aware of the criticisms being levelled at the national learning strategies (Alexander, 2010:36). To temper expressed disapproval the Department of Education reported that the strategies were developed so that schools could cultivate their distinctive character, take ownership of the curriculum and be creative (DfE, 2003:4). However, numeracy and literacy had also become the basis of success in all foundation subjects (and when developing creativity) too.

> '[To enable success in all foundation subjects primary schools are expected to] use the new Primary Strategy to extend the sort of support provided by the Literacy and Numeracy Strategies to all of the foundation subjects. The Strategy will draw on our programmes for developing modern foreign languages, PE and school sport, music, the arts, and creativity. It will also help teachers use ICT to support good learning and teaching' (DfE, 2003:5).

The attainment of specific subjects to support others (including creative thinking) is reminiscent of Sfards (1998) 'acquisition metaphor' where she claims '…concepts [or subjects] are understood as basic units of knowledge that can be accumulated, gradually refined, and combined to form ever richer cognitive structures. (ibid:5). The assemblage of knowledge, through mathematics and English, may sound akin to the learner construing meaning, but the physical act of knowing (i.e. the participation of a learner within the world) has been replaced with a 'permanent entity' (ibid:6). For example, in science a unit of knowledge would embrace a key scientific concept (perhaps Electricity or Light or Sound). Thus, the pupil could not be afforded the opportunity to epistemologically engage with a range of materials, cogitate, experiment and even think in similar ways to a scientist (so the critico-creative practices of Al-Ahaytham would be left wanting).

In 1999, the same year as the previous educational reform act, the Foundation Stage (for children aged 3-5) was introduced. The Qualifications and Curriculum Authority (QCA) set out six areas of learning, one of them being the inclusion of 'creative development'. The aim was to address a desire to provide children with opportunities to explore, develop and express their own original ideas through a wide variety of activities, enabling children to share ideas and stimulate different ways of thinking. Although how this related to a constructivist approach (or not) was not made explicit.

Nevertheless, the ideology was identified within the 1999 NC policy framework as something to build upon (DfEE and QCA, 1999:23).

The Rose Review (2009)

In 2009 the final report of an independent review of the then current primary curriculum was published (Rose, 2009). Similarly, to the early years learning goals it extended the previously narrower curriculum to include six proposed areas of cross-curricula learning that would enable teachers 'teach creatively' (ibid:16) and encourage both children and teachers to think 'outside subject boxes' (ibid:15). This review of the curricula was, according to Duncan (2010), welcomed by many practitioners and placed the child back into education resonating with an emphasis on a more child-centred approach (similar to the Plowden report).

The terms employed by Rose, in this review, included phrases such as, TC and thinking creatively. These expressions (and their synonyms) were arguably drawn from the NACCCE report. Referring back to this seminal document, and to the description of TC, however, there appeared to be more emphasis on teacher's practice rather than identifying exactly how child could be offered more agentive opportunities to be creative. Somewhat in contradiction, Rose also stated that children should, in conjunction with thinking creatively, also be encouraged to think critically. Thus, Fisher's critico-creative practices would be promoted if fostered appropriately by the teacher. However, the Rose review does not provide epistemological detail about how or who initiates and leads the creative classroom activities (teacher and/or child). It is suggested that this lack of explicit focus on either practitioner or pupil agency was due to the attempt to fit creative ideologies around, what Alexander (2010:183) referred to as, an already overly prescribed curriculum. The Rose review of the NC and its recommendations was not put into practice due to a change of government in 2010.

Ofsted (2003-2013)

In the interjecting years between the 1999 curriculum and the now current (2014) programme of studies (devised from the 2013 reform) Ofsted released four reports that related to creativity and school science. They were: Expecting the unexpected (Ofsted, 2003); Success in science (2008); Learning: creative approaches that raise standards (2010) and Maintaining Curiosity (2013).

Ofsted reported, in 2003, that the development of creativity was not related to a fresh (separate) pedagogy (such as creative teaching) but could be seen within all subjects (including science). This, they stated, occurred when a teacher was willing '…to observe, listen and work closely with children to help them develop their ideas in a purposeful way…[and] this focused engagement with the individual pupil – even within a group situation – is common to all creative work' (Ofsted, 2003:5). Speculatively, Ofsted could be referring to the nurturing of scientific creativity through social construction (de Oliveira Xavier et al, 2018). That is, they may have considered how the teacher and their pupils could compare and contrast epistemological understandings and have recognised the net worth of considering epistemological perspectives of knowing-how and knowing-what. However, there is also another way of perceiving the teaching approach advocated. Ofsted could also be suggesting that teachers identify individual expressions of scientific insights (within both individual and collective endeavours) and celebrate such. The former, considers the nature of scientific thinking that embraces plausible alternate ideas and suggestions about science and the latter foregrounds those children who can articulate scientific ideas and readily recognise the application of well-established and widely accepted science concepts.

Reiss (2000:70-71) provides an example of a year 9, secondary school, science lesson considering photosynthesis. The teacher (Mr Newman) invited his pupils to predict what would happen when he added sodium hydrogen carbonate to a container which enclosed a sample of pondweed in water. Two boys articulated their view of 'knowing-what' would happen, one by suggesting a gas that pondweed would 'give off', the other stated 'food' would be expelled from the submerged plant (*ibid*:70). Mr Newman subsequently celebrated what he thought was the correct response, but did not explore reasoning behind the two contrasting suggestions the boys offered.

Later on, in the same lesson, Mr Newman invited the students to experiment with shining a light on the pondweed for five minutes at a time. The consequence of light shone on the pondweed at three different distances (5cm, 10cm and 15cm) was to be observed. The pupils were asked to count the number of bubbles of gas bursting on the surface of the liquid within the fourth minute. However, a third student (George) suggested an amendment to the procedure (i.e. knowing-how), he suggested keeping the lamp at the same distance throughout the 15 minute experiment to observe if the number of bubbles increased per minute. The teacher commended this idea by inviting George and his partner to 'try this out' whilst others followed his pre-prepared instructions. It is unknown whether the results of George's investigation were discussed with the rest of the class (*ibid*).

Although alternative perspectives were offered by students in this lesson, the teacher remained focused on reiterating ontological clarification of scientifically correct 'facts'. By the end of the lesson, no consideration of alternate perspectives emerging from the students were re-considered. Consequently, the social construction and subsequent evaluation of the class's collective scientific understanding, as described by Author (2003) and Lave and Wenger (1991:15), was left wanting. George's methodological insights, recognising uncertainty in the teacher's pre-prepared experiment were left hanging. Roberts (2009:32-33) has highlighted, how this level of procedural understanding is important when encouraging students to be creative. She describes 'measurement uncertainty' as one aspect of scientific inquiry, alongside consideration of reliability, validity and calibration in data collection as well as the ability to interpret evidence (*ibid*). Roberts argues an open-ended approach is indicative of 'how real scientists work' (*ibid*:37), this is arguably relatable to the year six boys who investigated the effects of piercing holes in the cardboard crown. However, without teacher guidance substantive ideas of science can remain invisible. Black (2018) suggests that teachers should reconsider their pedagogy to more actively involve students in sharing and exchanging perspectives of scientific explanations. However, to acknowledge creative contributions from learners, teachers need to appreciate why there is value in recognising the nature of each other's epistemological ways of knowing.

Five years later, in 2008, Ofsted released a report which resonated with their 2003 review of teaching. In this examination of schools they looked at science lessons (and not the development of creativity) in both primary and secondary schools. They suggested that stimulating teaching and enthusiastic learning took place when the pupils suggested their own ideas. Then, in consultation with their teachers, evaluated their findings, akin to Black's (2018) description above. This report was arguably endorsing the growth of personalised scientific thinking through teacher-child interactions, through features that resonated with Davies's (2011) TC and T4C. However, there was little pedagogic guidance that extended beyond TC or T4C.

In 2010, seven years after stating that creativity is found in all disciplines (in the 2003 expecting the unexpected report) Ofsted stated that '...traditionally creative subjects, such as arts and English' would need to be incorporated into science and mathematics to promote creative learning (Ofsted, 2010:5). This suggests that in the intervening years between the two reports Ofsted appears to alter its stance on science being recognised as a creative subject in its own right. However, in the same document Ofsted also stated that:

> 'Assessment plays an important role in creative approaches to learning. Assessment that is used to encourage, guide and evaluate creative learning was highlighted as a priority in our survey visits, even where it was not yet embedded consistently in practice. Such strategies are also characteristic of effective teaching more generally' (*ibid*:4).

Thus it was recognised that assessment was a priority when fostering creative learning but it was not applied consistently to be effective. So, despite European projects, such as Strategies for Assessment of Inquiry Learning in Science (SAILS, see http://www.sails-project.eu/index.html) and Assess Inquiry in Science, Technology and Mathematics Education (ASSIST-ME, see https://cordis.europa.eu/project/rcn/108651/factsheet/en) involving the assessment of enquiry, in science, in numerous countries around the world, the national educational policy document (DfE 2014) for England does not clearly identify how practice should and could encourage all individuals to develop enquiry skills and practices that demonstrate learner's creativity. The lack of explicit acknowledgement of creativity in inquiry has constrained the extent of policy discourse centred on this crucial element of science education.

Following on from Ofsted's review in 2010 they disseminated a report called, Maintaining Curiosity: A survey into science education in schools. Ofsted claimed its findings could help support schools implement the new 2013 science curriculum (primary and secondary), which was implemented four years after the change of government (post Rose review). According to Ofsted creative science learning was observed when the pupils asked their own questions, made their own decisions, planned investigations and evaluated their findings. This remains, arguably, quite a narrow focus if creativity remains to only be promoted within an inquiry or investigational context.

An outdoor activity, engaged in by year 1 children (Author 2017), provided an insightful example of ways children can develop their scientific questioning skills when outside of a science classroom. The group of five-year olds were observed paddling in a small creek. They wondered why there were crab apples floating downstream. These pupils were heard to say, 'River's don't grow apples', 'Why are there so many apples in the stream?' and 'Why are they so small?'. These were agentive ideas, that were child-initiated potential lines of enquiry. However, the children did not engage in critically reviewing each others' ideas or even making suggestions about how they might investigate and evaluate their questions. Teacher intervention could have proffered value to the questions and mediated discussion about the natural phenomena of floating apples and/or water currents in a stream. This epistemic insight suggests how T4C tactics (Authors 2017 : 34) are often required to nurture creativity.

The Education Reform Act (2013)

Despite the Ofsted 2013 report supposedly being a critical document to consider when implementing the new National Curricula (DfE, 2013a; 2013b), the message of adopting creative approaches to promote curiosity is noticeable by its absence in the science programme of study. Similarly, to previous reforms acts (see 1999), the term creativity resided within the aims of the new document (ibid:6). Whilst in the programmes of study (primary and secondary) there are varying levels of reference to the synonyms of creativity. In art and design creative enactments were mentioned on several occasions. However, in science the only statements related to creativeness are mentioned within the non-statutory requirements. These include, "…identifying how these properties make magnets useful in everyday items and suggesting creative uses for different magnets" (2014 : 184) and "They should think about the properties of materials that make them suitable or unsuitable for particular purposes and they should be encouraged to think about unusual and creative uses for everyday materials. Pupils might find out about people who have developed useful new materials, for example John Dunlop, Charles Macintosh or John McAdam" (2014 : 177).

Each of whom applied their scientific and technological expertise and creativity to develop an air-filled pneumatic tyre; waterproof fabric and improve the way roads were constructed respectively. Wyse and Ferrari (2015) also emphasise the disparity between disciplines when they found that all current UK curriculum texts refer to creativity twice as much in the arts documentation than in other subject areas. This resonates with Robinson's (2009) belief that previous (and current) governments have not and do not appear to value, promote and explicitly support creativity within disciplines such as the sciences.

Discussion and Conclusion

Science educators (Roberts 2009) recognise that there are creative opportunities within inquiry activities in schools, but the ways that experimental work can promote scientific creativity is not explicit in national policy. For example, the national school inspectorate recognise what creativity in science (Ofsted 2010; Ofsted 2013) might look like, but there is an absence of clear policy directives in the curriculum to ensure it is embedded within the practice of all science educators. Practice is currently validated through the ways that standards are measured and judged (Newton, 2012). The assessment criteria in England for the public examinations taken at age 16 (i.e. GCSE's), for example, is not prescribed by National Policy, but the standards are 'set' from grades 1 through 9 (https://ofqual.blog.gov.uk/2018/03/02/gcse-9-to-1-grades-a-brief-guide-for-parents/). Yet, within the grade descriptors there are no explicit descriptions that explain which aspects of 'creativity' should be examined and judged. Additionally, the Ofqual (2015) assessment criteria for science lacks direct references to creativity, it does highlight how 'enquiry', evaluate and 'improve procedures'; 'connecting' data, information, detail and contexts are expected.

This paper has also attempted to illuminate how creativity has been understood through interpreting curricula documents and whether or not schools have been appropriately directed to nurture this key skill required to meet the challenges of the 21st century. As Abrahams, Reiss and Sharpe (2013) indicate what is taught in public examinations is that which is summatively assessed, and teachers' practice is 'routinely influenced by their considerations of curriculum targets and methods of summative assessment' (ibid : 210). Therefore, without explicit recognition in national curricular policy, which is also supported through assessment of creativity, there appears to be a lack of direction emphasising the value of innovation and inventiveness in science to address future concerns, issues and challenges the younger generation will face as the world population ages.

However, in the OECD (2015) policy document there is clear recognition that innovation is required to address pressing social and global challenges (including 'demographic shifts, resource scarcity and the changing climate' p. 2). Scientific originality is required (Pro-C) to solve what will undoubtedly be (some as yet unknown) world-wide problems. Having reflected on direction and guidance about creativity in educative policies (from the 1870's onwards) it would appear that successive National Curricula guidelines have recognised elements of teacher and pupil originality and innovation. For example, the 1999 reform act described how children should think both critically and creatively. The current curriculum also refers to developing curiosity and considers creative opportunities (albeit only in the aims and non-statutory requirements). There was also a where it was believed that UK education could accomplish great things (Durbin, 1987). It was during this optimistic decade that the Plowden review encouraged schools to promote a child-led (constructivist orientated) practice. This independence of learning was evidenced by the year 6 child trying to recharge her nine-volt battery by rubbing it on the carpet. However, Alexander et al, (1992) suggest there was no golden era of child-led creativity in science education and associated aspirations have been supplanted by curricula that have focused on numeracy and literacy, particularly in primary education.

Even if Plowden's child is recognised in policy the scientific objectives of lessons would still need to be socially mediated by the teacher to ensure concepts are not misconstrued (Driver et al, 1996), but how the scientific is to be communally constructed requires further reflection. Stephen Ball, in conversation with Mainardes (2015:184), stated that '…we need to think about the ontological basis of policy, we need to think about the relationship of policy to the way in which we think about how the social world works more generally'. Ball *et al* (2011) describe how teachers are receivers and translators of policy, therefore, as practitioners in classrooms, the ways they reconcile the intent of the NC with the external reality of the world in which we live, informs their pedagogical enactments. How they present or offer what-is-to-be-learned-about arguably resonates with what Ball would call a 'surface or deeper level epistemology'. The former denoting more straight forward expositions of substantive subject matter, the latter relating to a more involved, discursive approach, considering meanings and assumptions of players in the educative process. This is especially pertinent when considering, as Ball also notes, '….authors [of policy] don't make explicit the epistemological aspects' (Mainardes, 2015:185).

Whilst the emphasis of teaching and learning in the NC appears to remain focused on attainment in certain subject areas and neglects broader ontological and epistemological issues, perhaps it is not always the restraint that some imagine. Historical accounts suggest that creative scientific thinking can still be advanced under constrained circumstances. For example, Al-Alhaytham's own epistemic insights emerged whilst he was imprisoned (and under house arrest). During his confinement he began by critiquing and challenging the then current understandings of how light rays enter the eye. So, could the manner in which Al-Alhaytham (and even George Washington-Carver) creatively thought (and acted) beyond their cultural shackles serve as a parable for future generations? What we must ensure is that for future generations national policy is clear about the nature of creativity (in all its various forms), that we celebrate it (from little-c to Big-c), define it epistemologically and nurture it successfully across all ages and ability ranges. If policymakers do not define how originality should be recognised and nurtured pedagogically, as Taton (1960 : 157) indicates, we may make a mistake like Galileo, who, in 1690, upon first observing Saturn mistakenly saw a triplet of planets, instead of the single planet that is its surrounding ring. Nevertheless, it is undeniable that Galileo's decision to turn his handcrafted telescope to the celestial skies, as an alternative to those who were solely using these magnifying lenses to observe terrestrial bodies, was insightful and his focus of original thinking beyond established scientific knowledge of that time was innovative.

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