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A Sense of Wonder, arising from Aesthetic Experiences, should be the Starting Point for Inquiry in Primary Science

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Abstract

"It was through the feeling of wonder that men now and at first began to philosophise" Aristotle.
"Mystery creates wonder and wonder is the basis of Man's desire to understand"
Neil Armstrong.

The displaying of a sense of wonder when responding to aesthetic experiences of natural phenomena has been identified as having a significant impact on an individual's learning in primary science education. This paper attempts to review the significance of the influence of "wonder" arising from students aesthetic reactions to exploratory activities can have on their subsequent engagement and learning in science. Current challenges facing the teaching and learning of science in the New Zealand primary school context are identified and used to justify the need for change of approach to the teaching of primary science. The calls for more affective goals for primary science education are identified and linked to literature that explores the impact of aesthetic experiences on learning in science education. A tentative taxonomy that distinguishes different types and situations where aesthetic experiences may occur is presented. Finally, "Creative Exploration" an inquiry based model for teaching and learning in primary science is introduced.

Key Words: *aesthetic experiences, wonder, engagement, creative exploration.*

Introduction

Setting the scene

There are countless examples of quotes from eminent personalities from both the past and present that signal the importance of wonder on the human's mind to explore and understand our aesthetic experiences of the world in which we live. Rachel Carson,

(1956) identifies the notion of children having an "inborn sense of wonder" and her thinking, as expressed in the following extract from "The Sense of Wonder," which I have titled 'Something to think about,' not only highlights the significance of wonder and the influence of adult interactions, but also introduces the importance of feelings and emotions that set the scene for exploring the role 'wonder' can play in primary science education.

Something to Think About

A child's world is fresh and new and beautiful, full of wonder and excitement. It is our misfortune that for most of us that clear-eyed vision, true instinct for what is beautiful and awe-inspiring, is dimmed and even lost before we reach adulthood. If I had influence with the good fairy who is supposed to preside over the christening of all children I should ask that her gift to each child in the world be a sense of wonder, so indestructible that it would last throughout life as an unfailing antidote against the boredom and disenchantments of later years, the sterile preoccupation with things that are artificial, the alienation from the sources of our strength.

If a child is to keep alive his/her inborn sense of wonder without any such gift from the fairies, s/he needs the companionship of at least one adult who can share it, rediscovering with him/her the joy, excitement and mystery of the world in which we live. Parents often have a sense of inadequacy when confronted, on the one hand, with the eager, sensitive mind of a child and on the other, with a world of complex physical nature, inhabited by a life so various and unfamiliar that it seems hopeless to reduce it to order and knowledge. In a mood of self-defeat, they exclaim, "How can I possibly teach my child about nature -- why, I don't even know one bird from another!"

I sincerely believe that for the child, and for the parent seeking to guide him/her, it is not half so important to *know* as to *feel*. If facts are the seeds that later produce knowledge and wisdom, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow. The years of early childhood are the time to prepare the soil. Once the emotions have been aroused -- a sense of the beautiful, the excitement of the new and the unknown, a feeling of sympathy, pity, admiration or love -- then we wish for knowledge about the object of our emotional response. Once found, it has lasting meaning. It is more important to pave the way for the child to want to know than to put him on a diet of facts he is not ready to assimilate.

From *The Sense of Wonder* by Rachel L. Carson (1956)

Despite many pronouncements over the past ten years of the importance of the affective notions of awe, wonder and interest on children's engagement and learning in primary science education, there are indications that primary science education in New Zealand is in a state of crisis and poses some significant challenges for those involved with the teaching and learning of science in primary schools.

Defining the Challenges

The lack of status of science teaching and learning in a crowded curriculum and the decline in students' attitudes towards further learning in science education are two major areas of challenge to New Zealand primary science educators. Despite the availability of many quality teaching and learning resources, science as a curriculum area in primary schools is generally perceived by teachers and principals as being of a low priority. A recent NZCER survey found that only 2% of primary school principals identified science as a curriculum area within their schools that would be receiving a professional development focus, whilst nearly 70% positively identified literacy and numeracy. Interestingly, over 50 % of the same principals identified inquiry learning as a focus as well. Inquiry learning has become a major focus within New Zealand primary curriculum and its development may provide one of the causes for the decline in science teaching and learning in primary schools. Findings from the 2006 TIMSS showed that there had been a significant decline in the hours spent teaching science by teachers of year 5 children, from 66 hours in 2002 to 45 hours in 2006. This decline in teaching instruction was mirrored by a similar decline in the student's achievement. After increasing from 1994 to 2002 student's achievement levels dropped back, in 2006, to 1994 levels. It could be argued that this lost status of science amongst principals and teachers is reflected in student's attitudes towards being involved in school science activity.

Attitudes towards science

The well documented decline of secondary school students' interest in being involved in further studies in science is becoming increasingly evident in students in primary school (Crooks & Flockton, 2003; 2007; Murphy, Beggs & Russell, 2005). The NEMP 2007 survey on New Zealand student engagement in school science activity further highlights the fall-off in engagement between year 4 students and year 8 students with a significant increase in students displaying negative attitudes towards the science activity they were involved in at school. Both year 4 and year 8 students expressed concern that they did not do interesting things in science. On a positive note, many children expressed a genuine concern about the importance of science and they were keen to learn more. These findings suggest that the goal for science educators and teachers is to provide a science curriculum that focuses on investigating and exploring science contexts that are interesting and of relevance to the learners involved. The purpose of an inquiry process approach in science must be to allow the learners to develop a sense of scientific literacy that allows them to start to develop an appreciation of the power, beauty and wonder encompassed in the nature of science.

The ever increasing call for "scientific literacy for all," as encapsulated in the OECD (2006) PISA project and Tytler's (2007) "contention that science education needs to diversify its emphasis beyond focusing on canonical abstract ideas, and place an emphasis on the nature of science and the way it operates" (p.31), identify the affective domain as an insight to a way forward for primary science educators. As indicated by Carson's "sense of wonder," most young children experiences of natural phenomena promote a sense of curiosity and wonder. This natural curiosity and interest, which motivates young learners to be engaged to seek explanations, needs to be enhanced and recognised as an essential element of science programmes in primary schools (Milne, 2008, Fried, 2001; Bell, 2001). The challenge for primary school science teachers and educators is to develop teaching and learning approaches that showcases science education in such a manner that will both appeal to teachers and their students as being significant and worthwhile and also counter the decline in attitudes towards science being

expressed by children, resulting in greater engagement and the development of scientific understandings by those involved.
This decline in primary school children's attitudes towards being involved in learning in science has also resulted in the call to promote the development of affective attitudes like curiosity, awe, wonder and interest as essential goals of science education (Millar & Osborne, 1998; Arcus, 2003). Similarly others, Dahlin, (2001), Girod and Wong (2002) and Wickman, (2006, p.38 cited in Tytler, 2007) claim that a more phenomenological - aesthetic approach is required. That is an approach to teaching and learning in science that stresses the importance of aesthetic experiences of natural phenomena that leads to the development of a sense of fascination by the learners involved. Wickman (2006) places aesthetic experiences as a key interconnecting element that links the learner with the phenomena involved and provides continuity for further application and learning.

Thus a feature of primary science education programmes must be the significance of exploratory activities that, with teacher direction and input, provide aesthetic experiences of natural phenomena that will promote a sense of wonder leading to a desire for understanding and explanation of the phenomena for the learners involved.

An explicit place of wonder within science education

Affective domain

This current expression of concern about the importance of attitudinal development in science education is not just a recent phenomena. Gardner (1975), in his summary of an extensive review of research into attitudes to science, recognised that a substantial body of knowledge already existed about factors which influence students' attitudes towards science. His call for the need to move the findings of this research into school practice is still relevant today and provides justification for the further exploration of the role of wonder in the science classroom. Gardener contended that the findings of this research should be used by classroom science educators to: "stimulate joy, wonder, satisfaction and delight in children as a result of their encounters with science" (p.33). These attitudes of joy, wonder, satisfaction and delight, identified by Gardner (1975), coupled with the natural curiosity suggested by Bell (2001) and the indicators presented by the exemplar development project Ministry of Education (2003), can be described as descriptions of behaviours that fit within the affective domain, that is, behaviours dealing with feelings, attitudes and values (McInerney & McInerney, 2002; Krathwohl, Bloom and Masia 1964 cited in Tamir1998). In his review of assessment in the affective domain, Tamir (1998) also contends that this domain deals with attributes such as feelings, attitudes, dispositions, preferences and orientations. The experiencing and showing awe, wonder and interest indicators from the exemplar matrix can be viewed as examples of these affective domain attributes.

Imaginative Education

Wonder is identified by Egan (1997) as one of the tool kits used by learners as they develop their "romantic understanding", the third of five stages of understanding that are featured in the work of the Imaginative Education Research Group (Tyers, 2008). Egan (1997) suggests that the content of science education at the romantic stage should "best be able to stimulate the student's sense of awe and wonder, p. 218" and in the process ensure ready engagement by the learners involved. Egan further contends that the curriculum content should be presented in short, sharp burst of no more than 15 minutes at least three times a week. Whilst most recent approaches to the teaching and learning in primary science education would advocate that wonder should be viewed as an integral part of the inquiry process, Eagan suggests that these short, sharp learning experiences should, over time, "aim to build gradually and randomly a particular level of knowledge about the world that stimulates bit by bit wonder and awe at being alive in this world at this time (p 219)." The notion suggested here that there is a need to develop a sense of awe wonder about the world is similar to the contention that science education should focus on the role aesthetic experiences of natural phenomena can have on children's engagement with their learning in science.

Aesthetic Approaches

It is claimed that more phenomenological - aesthetic approaches to teaching and learning needs to be implemented in science education classrooms, if students are to become engaged with and continue their studies in science (Dahlin, 2001; Girod and Wong, 2002; Wickman, 2006). These are approaches to teaching and learning in science that Wickman suggests "shows the intimate connections between learning science and interest in science (p145)." They are approaches that stress the importance of the contribution that aesthetic experiences of natural phenomena play in students learning and engagement as they explore scientific phenomena. Dewey's (1934) notion of educated experiences, or fulfilled experiences of phenomena over time, is described by Girod and Wong (2003) as being dramatic events. They contend that these events, which they refer to as aesthetic experiences, can have a significant influence on learning in elementary school science. Similarly, Dahlin (2001) also contends there needs to be a greater "emphasis on the aesthetic dimension of knowledge formation" (p.130). He defines aesthetic as "a point of view which cultivates a careful and exact attention to all the qualities inherent in sense experience …. an approach to natural phenomena would not merely be to appreciate their beauty, but also understand them" (p.130). It is claimed that children involved in aesthetic experiences of nature can develop a sense of fascination (Godlovitch, 1998), which can generate a sense of anticipation and can lead children to a depth of engagement and learning (Girod & Wong, 2002). It can be argued that there is a strong similarity between the notions of awe and wonder and the elements of fascination and anticipation that children, engaged in aesthetic learning experiences, may experience. The awe and wonder factors, often referred to as the "wow" factors (Feasey, 2006), can become the focus or motivator for further thinking and enquiry. It can be argued that this process is similar to those that lead to the generation of a sense of internal feeling, similar to Dahlin's (2001) notion of aesthetic perception and Godlovitch's (1998) sense of fascination. Godlovitch suggests that an aesthetic experience could be defined "as an elemental mode of awareness, one special way we make contact with experiential content, which is the focus of attention of a special sort of appreciation….aesthetic appreciation is a primary perspective involving those qualities of sensation and affect that draw us to, and repel us from, the world of experience by way not of survival and benefit, but of fascination" (p.3). Godlovitch contends that fascination develops very early in life and suggests that, because of the complexity of the sensory and affective dimensions of aesthetic experience, "fascination stands proxy for a cluster of terms all of which accent a powerfully personal bond (analogous to affection) that develops in aesthetic experience between the subject and object of experience." These terms include "attachment, contact, capture, engagement, encounter resonance and the like" (p.3). Wickman (2006) refers to Kant's definition of aesthetic experiences as the judgments which are related to experiences - that is, the judgments that are made as one communicates one's feelings about the effects of the experiences. For research purposes, Wickman defines aesthetic judgments "as utterances or expressions that either deal with feelings, or emotions related to experiences of pleasure or displeasure, or deal with the qualities of things, events, or actions that cannot be defined as qualities of the objects themselves, but rather are evaluations of taste –for example, about what is beautiful or ugly" (p.9). As with Girod and Wong, Wickman applies a Deweyan perspective and examines aesthetic experiences from both a positive and negative view as they appear as part of the practice and the life of students involved in science education activity. Wickman focuses on the aesthetic judgments and the language used as student react and communicate their feelings and emotions about the experiences of phenomena. It particular, Wickman applies an imaginative education perspective as he examines "binary opposites" (Eagan, 2005) like beautiful/ugly and pleasure/displeasure. It could be argued that the contention that the affective elements, associated with aesthetic experiences, may strongly influence how children approach their learning is supported by Egan's (2007) proposal "Whatever content is to be dealt with needs to be attached to students emotions in some way… and needs to be part of what is dealt with in the class" (p.19).

Whatever teaching learning approach is used, it appears that there needs to be a period of exploratory activities that, with teacher direction and input, provide aesthetic experiences of natural phenomena that will assist the promotion of a sense of wonder, leading to a desire for understanding and explanation of the phenomena for the learners involved.

Wonder and its relationship with aesthetic experiences

The links between awe and wonder, and aesthetics and fascination are further inherent in Goodwin's work (1994; 2001), where he contends that there are three aspects of wonder that directly relate to the teaching and learning of science: "Wonder about", "Wonder at" and "Wonder whether". Goodwin's suggestion that "Wonder about" pertains to questions relating to: How does it work? What would happen if? Why? When? What next? is similar to the notion of anticipation that Girod and Wong contend evolves from initial fascination. The notion "Wonder at," pertaining to exclamations like: wonderful! wow! how interesting! how exciting! how beautiful!, relates to the appreciation phase of an aesthetic experience of nature (Dahlin 2001). The third aspect; "Wondering whether" includes a values aspect and involves value-laden questions pertaining to: Should I do this? Must I do this? Would this be better than that? Is it right? Why is this significant /important? These aspects of wonder highlight the personal, or humanising of the science content that may be involved as science activity is presented in contexts that are engaging and contextually relevant. It could also be argued that these expressions of thoughts and feelings, relating to values and actions, relate quite closely to Wickman's empirical findings of the role aesthetic experiences have for learning in science and discussed next.

Investigating wonder in educational settings

Aesthetic experiences were found by Wickman (2006) to play four different roles in learning science.

1. "Their continuous nature and the transforming of the normative aspects of experience" – that is, the students involved learned how to act and work in the science class. Positive aesthetic judgments were used by teachers to direct the learning processes.
2. "They were continuous with and transforming the cognitive aspects of experience"- that is, they were integral to the facts and reason of science.
3. They could be seen to "partake in transforming and making diverse situations continuous and so in learning science" – that is they were involved in connecting students prior informal experiences with the scientific experiences of the science class.
4. "the immediacy of aesthetic language plays an important role in functionally sharing and communicating experiences of relevance for proceeding with the scientific class activities (p.136)."- that is, aesthetic language is used effectively to convey a summary of extensive experiences over time by the use of single plain aesthetic words. When Wickman applied the findings of this university-based study to a primary and middle school study he concluded "Learning science from the primary school to the tertiary level is in necessary and inseparable ways dependent on aesthetic experience (p145)."

A base line study conducted by McWilliams (1999) that explored how children express wonder and curiosity identified 9 classroom indicators including; questions, observations, hypothesis making, theories, art, imaginative play, stories, myths, and conceptual play in language, In the same study, McWilliams identified 16 teacher actions necessary for providing opportunities for wonder to emerge within the classroom culture that included; eliciting theories and predications associated with observations and experiences, risk taking by children when making hypothesis, active listening by the teachers involved, positive and humanising responses by the teachers to children's questions and answers, specifically modeling wonder type questions when interacting with the children, having a time for messing about with science and allowing children to explore their own questions. It could be argued that these indicators tend to relate to normal classroom science activity associated with a co-constructive approach to teaching and learning. There was no reference to outside school experiences that may influence children's notion of wonder and activity or thought that may develop children's development of and use of wonder.

Whilst exploring primary school children's appreciation and interpretation of natural objects presented on a nature table, Tomkins & Tunnicliffe (2007) discovered that a significant number of children, when asked to choose an object to photograph and talk about, used both wonder and aesthetic appreciation elements when deciding what objects to select. The children tended to use terms like "I just really like it", "they are so pretty", "its just weird and interesting," indicating that they were expressing a type of aesthetic appreciation that was influenced by the structure and form of the object and the sensory perception they experienced.

Types of aesthetic responses

Solomon (2004) identified a range of sensory delights that children perceive as the experiences that are enjoyable and engaging. Soloman has suggested that there is a continuum of perceptions that range from the first encounter, which initiates an awakening of senses leading to a growth of wonder, followed by marveling, before becoming curious resulting in activity to seek causes, which in turn can lead to the development of scientific explanations. Whist exploring the questions that came into the children's thinking when involved in sensory activities, Soloman noticed that there were a number of questions that were of a spiritual nature. Spiritual was one of the seven categories that Milne (2005) proposed as being useful for classifying aesthetic experiences causing or generating a sense of awe wonder and interest. Spiritual experiences could be both secular and religious in nature. The other classifications (see table 1) include utilitarian, fashion/marketing, value /respect, beauty, mathematical, personal and pure curiosity.

Spiritual	Can be from both a religious and secular perspective	Statements or feelings expressed when looking at stars and appreciating nature. Direct reference to God or a creator
Utilitarian	Experiences motivated through need or problem solving	Expressions or feelings communicated when faced with and over coming challenges associated with problem solving
Fashion/Marketing	Used by marketing to set trends can be superficial	Expressions or feelings expressed when affected by marketing or fashion
Value/Respect	Appreciating the power of nature or the power of position	Expressions or feelings expressed when confronted with - Awesome power of nature (Tsunami), Awesome influence of the Pope as signaled by the 6 million attending the funeral
Beauty	Appreciation of natural form and structure of nature	Expression or feelings expressed as one responds to interactions or close encounters with flowers, gems
Mathematical	Appreciating the natural patterns of nature both in form as for beauty and abstraction for number	Expression or feelings expressed when experiencing the beauty of form and patterns and time associated with nature/ exploring and appreciating the structure and rules associated with working with very small or very large numbers
Personal Enjoyment or pleasure	Personal experiences, interest, over time,	Both teachers and students will have them. And they relate to individual attachment /reaction to both pleasurable or non pleasurable experiences
Curiosity	Pure curiosity, the affective dimension that drives humans to understand reality	Being curious is usually an attribute of a person doing science. Often the domain of children and scientist

Table 1 Types of experiences that may cause or generate a sense of awe, wonder and interest

This classification of types of experiences arose from the author's involvement in the development of the science assessment exemplars (Ministry of Education, 2004). The exemplars identified the demonstration of awe, wonder and interest in science as a key aspect of learning for the goal of "Developing interest and relating science learning to the wider world" (Arcus, 2003; Ministry of Education, 2004). The project developers identified the following set of dispositional indicators that science education seeks to foster in student's at all levels:

- Display curiosity about the world around them.
- Demonstrate enthusiasm and excitement about how science works.
- Take an interest in a particular science topic.
- Become absorbed in a science related activity.
- Pursue science interests without prompting, outside the formal learning environment.
- Display initiative and commitment when seeking answers to their questions.
- Express awe and wonder and enthusiasm about an observation, experience or idea/explanation.
- Develop and declare an interest in some aspect of science or the environment.
- Persevere to solve problems and overcome difficulties while pursuing their own interest in science.

The dispositional indicators used above were strongly influenced by Carr's learning dispositions that have become a corner stone of pre-primary school education in New Zealand. Many of the above indicators are easily identifiable in pre-school children's activity in early childhood centres and informal learning situations. A goal of primary science education should be to continue to support and foster those dispositions, including that sense of wonder that all young children posses, or, as Rachel Carson desired, when "words and pictures to help you keep alive your child's inborn sense of wonder and renew your delight in the mysteries of earth, sea and sky." Creative exploration (Milne, 2008) that is briefly introduced next is an inquiry approach for teaching and learning that is based around enhancing students' innate sense of wonder as they seek understanding in science.

Creative Exploration - Doing science in the primary school.

Creative exploration involves children doing Science. It is an approach to science teaching and learning that models many aspects of the scientific process, or how scientists work. It requires both the teachers and students to make the science and scientific processes involved explicit. It is about children's science; children personalising their science activity, leading to their development of creative explanations of natural phenomena. It requires the children to be involved in exploration, inquiry, explanation and making connections and is often, can be, should be, based around or ignited by aesthetic experiences that promote affective and often emotional responses associated with the dispositions like fascination, anticipation and engagement and awe, wonder & interest that spark curiosity and can lead to the use of scientific inquiry to develop explanations of natural phenomena.

Creative Exploration: Introducing the approach

This sequential and/or cyclic model of exploring for understanding in children's science is a teaching and learning approach that is based on the assumption that children naturally seek explanations for experiences that have some affect on their feelings, attitudes and the manner in which they think about, or view natural phenomena. Children will often construct creative explanations when seeking to understand and explain the phenomena involved in their aesthetic experiences. Rich aesthetic experiences can lead to the development of a sense of fascination that, in turn, leads to a greater degree of engagement in the learning process. The outcome of this engagement is a greater depth of understanding, especially if the learner involved has communicated and justified their ideas with others. In a teaching and learning situation, children participating in rich aesthetic experiences of natural phenomena can be guided by informed facilitation towards a greater depth of personal understanding. This authentic process of enquiry not only leads to the development of personal conceptual understanding, but also to the development of procedural knowledge and skills and a tentative appreciation of the nature of science. Although the approach is presented here in a linear fashion, it should be viewed as cyclic in nature. The cycle can follow the whole process, or it may only complete parts of the process. The more elements of the process used deepens the depth of engagement and subsequent understanding.

Creative Exploration		
Explore	a problem, situation, phenomenon, artifact, model, event, story.	**Wonder**
Observe	What is happening? What changes happened? What materials are involved? What are the main parts? What are the key aspects? What do these parts/structure do?	**Wonder about**
Identify evidence	What is the cause and effect of changes? What is the function? What parts are interacting with other parts? What are the outcomes of these interactions? What trends and patterns keep occurring?	
Create explanations	Personal explanations supported by evidence are created and processes to test them are planned	**Wonder at**
Investigate	Find out, measure, compare, verify, test, clarify identify	
Evaluation	A self- evaluation of these investigations may lead to, new or modified explanations, doubts about existing ideas or tentative conclusions. These tentative explanations need to be communicated to others for peer evaluation and feedback	
Further investigation	Evaluated explanations can lead to: re-exploration, seeking further explanation, leading to further investigation	**Wonder whether**
Making Connections	Explanations are used or applied to make sense of or clarify other contexts where similar phenomena are involved	

Table 2. Sequential elements of Creative Exploration model for developing personal understanding in primary science

Creative exploration is co constructive inquiry learning approach to teaching primary science that requires both the teacher and learners to be involved in doing science A fundamental cornerstone is that the science is made explicit. At any time, the teacher and the children will be able to answer the question - What makes this activity I am involved in science? This assumes that both the teacher and the learners have a personal understanding of what science is and that aspects of the nature of science are discussed, explored and applied in a natural inquiring manner. As already discussed, children use their previous experiences and imagination to create explanations for experiences of natural phenomena that intrigue or interest them. For these ideas to be classified as science ideas, the children need too be able to identify and share the evidence they have used to formulate their explanations. These explanations, supported by evidence, are what can be loosely named as 'children science.' They are not the same as 'western science,' but have followed a similar process in their formulation. Children's thinking about natural phenomena is at the heart of primary science. Children's creative explanations of these phenomena that are supported by evidence should be the starting points for all school science inquiry. Children's creative explanations are the building blocks for further learning. They are used by children as evidence to support their thinking and view of the world. We must recognize young children's creative thinking as 'children's science.' It is important that primary school children develop an appreciation that there may be other explanations for the same evidence. Therefore, as already stated, it is important that teachers and pupils need to have an explanation for what the term 'science' means. From my perspective, I have found the following explanation suitable for both teachers and students.

Science has two aspect - ***science is the current accepted explanation for nature (nature standing for natural phenomena) and the process by which the evidence used to support the current explanation is developed, tested and approved by a community of scientists.***
If both teachers and students are making the science explicit whenever they are involved in a science activity, they will be doing science, rather than learning science. They will be testing their explanations against the evidence they have identified whilst planning and carrying out inquiry activity. They will be evaluating the processes they and others have used when generating and processing their data.

Summary
As already stated, 'creative exploration' is an approach to teaching and learning that models many aspects of scientific inquiry. It requires an exploratory phase that essentially provides the children with rich learning experiences about phenomena. Out of these aesthetic experiences, authentic questions can be generated that the children can investigate to create and test theirs and others explanations. It requires enthusiastic teachers who personalise the science activity and not only provide support for, but also challenge the children's thinking as they develop and share their explanations. They support the children as they move their creative thinking' from 'children's science' to the creative world of scientists.

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