

## Chapter 2

# Engagement and Aesthetic Experience in Science Education

*Experience is the result, the sign, and the reward of that interaction of organism and environment, which, if it is carried to the full, is a transformation of interaction into participation and communication [...] Experience in this vital sense is defined by those situations and episodes that we spontaneously refer to as 'real experience'; those things of which we say in recalling them 'that was an experience'.*

John Dewey, in *Art as Experience*, p. 22, p. 37

*Contact with science by non-scientists and deeper involvement in science by scientists can only be truly beneficial and fulfilling to the individual and society when science itself is given deeper foundation in self.*

Klaus Witz, in *Science with Values and Values for Science Education*, *Journal of Curriculum Studies*, vol. 28, p. 597

*The only acceptable point of view appears to be one that recognizes both sides of reality [...] the physical and the psychic [...] it would be most satisfactory if physics and psyche [...] could be seen as complementary aspects of the same reality.*

Wolfgang Pauli, in dialogue with Carl Jung, in Mindell's *Quantum Mind: The Edge Between Physics and Psychology*, p. 19

*I was sitting by the ocean one late afternoon, watching the waves rolling in and feeling the rhythm of my breathing, when I suddenly became aware of my whole environment as being engaged in a gigantic cosmic dance. Being a physicist I knew that sand, rocks, water, and air around me were made of vibrating molecules and atoms, and that these consisted of particles, which interacted with one another by creating and destroying other particles. I knew also that the earth's atmosphere was continually bombarded by showers of 'cosmic rays', particles of high energy undergoing multiple collisions as they penetrated the air. All this was familiar to me from my research in high-energy particles, but until that moment I had only experienced it through graphs, diagrams, and mathematical theories. As I sat on that beach my former experience came to life; I 'saw' cascades of energy coming from outer space, I 'saw' the atoms of the elements and those of my body participating in this cosmic dance of energy, I felt its rhythm and 'heard' the sound. (Capra, 1977, p. xii)*

What Capra (1977) describes here is a 'wonder-full' and, in fact, an awe-filled experience. Some might even talk of a 'mystical' experience. Apparently, this particular

experience is quite unique and, as such, rather unrealistic to be expected of students—let alone young children—in traditional classroom settings. However, the above passage also describes an experience that points to two crucially important factors, with implications for school science education, namely, (a) the perception of physical reality by, and its relationship with, the self and thus to the role of phenomenology in school science education and (b) the process of engaging students in science and the students' transformation of outlook, as a result of their experience. This chapter will deal with the latter.

Indeed, it has been recognized that engagement with science is central to science education, albeit a complex and challenging problem to be tackled by science teachers and curriculum designers (Hadzigeorgiou & Stivaktakis, 2008; Klassen & Froese-Klassen, 2014b; see also Duschl et al., 2007). The complexity of the process of engagement can also be seen in the fact that research findings on students' engagement cannot be 'neatly' categorized (i.e. social/emotional development, cognitive development, physical behavioural development). However, the main features, and, in fact, the benefits, of a truly engaging experience can be summarized as follows (see Fleer & March, 2009):

- Student learning extends beyond the classroom.
- Students transfer learning to different times and contexts.
- Students demonstrate long-term satisfaction with the learning process.
- Students reflect on their learning (e.g. in informal discussions, in journal entries).
- Students demonstrate long-term satisfaction with the learning process.

Of course, it would be a truism to state that, unless children and older students alike become involved with the learning process, 'significant' learning cannot take place. For this is quite self-evident. What is not self-evident though is that there may be involvement with the learning process, and yet learning may not take place. How can this be? The answer is that students may become involved with the teaching/learning process but not with their object of study per se (i.e. science content knowledge).

Cognitive conflict is a strategy that inevitably results in involvement with the object of study. And this strategy, because it can facilitate conceptual change, has been dominant in science education. However, over the last decade, there has been an increasing interest in alternative ways of understanding school science that have been called 'aesthetic' (Girod, 2007a; Girod, Rau, & Schepige, 2003; Wickmann, 2006), 'transformative' (Pugh, 2004, 2011; Pugh & Girod, 2007), and 'romantic' (Hadzigeorgiou, 2005b; Hadzigeorgiou, Klassen, & Froese-Klassen, 2012). While the first two kinds are based on Dewey's (1934) notion of 'aesthetic experience', the third derives directly from Egan's (1997) recapitulation theory and more specifically from a particular kind of understanding that is called 'romantic' (see Chap. 3). Despite the differences among these alternative ways of understanding, they share one common element: the facilitation of deeper involvement with science.

Are these approaches cures or even treatments for students' 'anorexia learnosa'? The evidence from those really few studies (see last section in this chapter) that report on the effect of aesthetic, transformative, and romantic understanding on

science learning is certainly positive and quite encouraging (e.g. Girod et al., 2003; Girod, Twyman, & Wojcikiewicz, 2010; Hadzigeorgiou, 2012; Hadzigeorgiou, Klassen, & Froese-Klassen, 2012; Pugh, 2002, 2004; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010a; Wickmann, 2006). However, given the complex nature of the learning process, the question how to get students involved with science content knowledge still remains quite pressing and challenging. The idea of 'aesthetic experience' deserves particular attention when it comes to encouraging involvement with science content ideas, which, of course, can be seen as a prerequisite for an aesthetic/transformational experience (Hadzigeorgiou, 2012; Hadzigeorgiou & Garganourakis, 2010).

This chapter will attempt to shed some light on the problem of student involvement with science and will then discuss the notion of aesthetic experience and (the need for) aesthetic approaches in science education. However, a discussion of the role of cognitive disequilibrium and cognitive conflict in the process of engagement, as well as the limitations inherent in the notion of cognitive conflict, are imperative.

## 2.1 The Problem of Engaging Students in Science

The problem of motivation in connection with learning is well known (Brophy, 1987, 1999; Bruner, 1966; Franken, 2001; Raffini, 1993). However, what has not been recognized or adequately addressed in the past is students' motivation with regard to the content of learning (Pugh, 2004). More specifically, in the context of school science education, what is at issue is not just the problem of students' motivation in general or the problem of considering the affective component of learning science but their motivation in connection with the object of study itself, for there is a distinction to be made between participation in a learning activity and involvement with the object of study itself (Hadzigeorgiou, 1999; Hadzigeorgiou & Stivaktakis, 2008). Pugh also distinguishes between peripheral things (e.g. humour, interaction with peers, flashy demonstrations) and engagement with science content.

It goes without saying that during participation in an activity, the object of study can be disconnected from the emotions of the student, which can arise mainly from participating in the activity. For example, a student may be interested in investigating the socio-scientific issue of genetically modified food or the topic of magnets in a cooperative setting and enjoy them, but his/her emotions may arise from the social context of those activities and not from the objects of study themselves. In contrast, when there is involvement with the object of study, emotions are not disconnected from it (object of study).

Although emotions are not the same as the motivation to learn, in the sense that they (emotions) do not necessarily have a goal orientation associated with them, emotions are nevertheless crucial for initiating involvement with the object of study itself and therefore discourage what Dewey (1934, 1966) had called the 'spectator

theory of knowledge'. Certainly, contemporary learning models are not based on such a theory, but on constructivist theories, since they encourage students' active participation in learning activities. Yet 'most theories of constructivism remain within the dualistic framework which Dewey opposed' (Dahlin, 2001, p.456). This dualistic framework, in fact, is encouraged by science teachers, in the case in which their main interest is how to 'sugar-coat' school science, as Pugh (2004, p. 194) put it. It is quite apparent that 'sugar-coating' can motivate students, but it is debatable whether it can lead students to become involved with school science, as their object of study (Hadzigeorgiou, 2005a; Pugh & Girod, 2007).

The problem, therefore, for science educators and science teachers is how to move away from that dualistic framework by encouraging students' involvement with their object of study. What should become abundantly clear, however, is that the process of involvement is a complex one.<sup>1</sup> Although interest may be identified as a crucial factor that can encourage involvement (see Klassen & Froese-Klassen, 2014b), there are such factors as personal identity, purpose, and awareness of the significance of the object of study that can determine, to a large extent, student involvement (Hadzigeorgiou, 2005b). Here I will discuss three factors/problems, which have been documented empirically, and the questions raised in regard to the first one, that is, personal identity.

The first factor concerns the role of personal identity, which is central to the process of involvement. According to the literature, the construction of personal identity takes place through social relationships (Apple, 1999; Gallas, 1997), through lived experiences of practice (Wenger, 1998), and through narratives (Sfard & Prusak, 2005; see also Brown, 2004). Contrary to the prevalent modernist notion of identity as something predefined and fixed, identity is considered 'in terms of the possibilities, in terms of freedom, and the power to choose' (Greene, 2000, p. 295; see also Greene, 1988, 1991). The implications of this idea for school science education are important: the science classroom becomes a place where students and teachers negotiate ways of being, knowing, and acting; and science learning is considered not just a matter of acquiring or constructing knowledge but also a matter of deciding what kind of persons students are and what they aspire to be (Brickhouse, 2001; Cleaves, 2005; Hadzigeorgiou & Garganourakis, 2010; Kozoll, & Osborne, 2004; Reveles, Cordova, & Kelly, 2004). These implications, of course, raise important questions in regard to science teaching and learning, as I will discuss below. But first let me discuss the other two factors related to the process of student involvement with science, namely, that students' worldviews and the object of study itself.

In regard to the students' worldview (which is related to the idea of personal identity), one has to recognize the possibility of a clash between their worldviews and school science. This can happen if a student's metaphysical frame is in conflict

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<sup>1</sup> Researchers in psychology use the term 'engagement' to refer to the intensity of one's involvement with an idea, a task, and an activity. The complexity of the process of engagement can be seen in the fact that it has behavioural (e.g. persistence), emotional (e.g. interest), and cognitive (e.g. learning outcomes) components. It has been found that 'engagement is associated with positive academic outcomes' (Fredricks, Blumenfeld, & Paris, 2004, p. 87).

either with the teacher's metaphysical frame or with that of school science. For example, a student may experience a sense of beauty, which though derives from his/her own metaphysical frame and not from that of school science (i.e. when the latter is presented in a way that its aesthetic dimension is absent). Another student, who enjoys reading mysteries or feels inspired by a sense of wonder in reading science fiction and other relevant magazines, may very well find that a teacher's approach to teaching science is rooted in mechanistic, reductionist, and 'scientific' view of science. In considering the issue of the incompatibility between the teacher's personalized worldview and that of a student (see Cobern, 1991, 1996, 2000), one can see how involvement with science, as students' object of study, becomes problematic. This issue of incompatibility, of course, becomes extremely crucial in addressing the problem of involvement with science in the case of students from other (non-Western) cultures (Hadzigeorgiou, 2005b).

As far as the third factor is concerned (which may also relate to personal identity and worldview), the object of study determines to a large extent whether students will engage in science. For example, some students may become involved with the study of evolution and the greenhouse effect but not with the study of chemical bonding and the laws of thermodynamics. Or, some students may become involved with physics and earth science but not with chemistry (Hadzigeorgiou, 2005b; see also Cobern, 1996).

However, there are two other factors that may also account for the problematic nature of student engagement in science. The first, which may or may not relate to personal identity, is the fact that involvement itself is something personal and is therefore determined by how meaningful the object of study is (i.e. how closer the connection between the object of study and self is). A female student, for example, who is helped to connect the law of universal attraction to her own menstrual cycle, may very well become more involved with the science lesson, in comparison with a male student who is presumably interested in sport and is helped to understand Newton's laws through the motion of a soccer ball. As for the second factor, prior experience may also play a role in the process of involvement. A student, for example, who has already burned her mouth by biting at a slice of pizza that did not appear at first to be too hot or who has experienced the shaking of the earth and had the feeling of impending death, as a result of an earthquake, will more likely find more meaningful the concepts of heat capacity and simple harmonic motion, respectively, than students who did not have such prior experiences. Although imaginative engagement with ideas can and does take place through unfamiliar, remote, and strange situations and events, as was discussed in the previous chapter, the possibility of the creation of existential meaning, through the connection of science content knowledge with one's self and personal life, and therefore with something that is already familiar, is also something to consider (Hadzigeorgiou, 1997, 2005b).

Of all factors, however, personal identity seems to be the most critical factor contributing to, or rather determining, involvement and learning outcomes. The issue of personal identity, however, begs two questions: (a) Are identities only the product of significant narratives? (b) Are students to be viewed only as products of social interaction? For Sfard and Prusak (2005) 'identities are products of discursive

diffusion' (p. 18). So, in this sense, narratives become the most important determinant of students' involvement with the object of study and hence a determinant of their success in school.

On the other hand, the fundamental premise in Gallas' (1997) work is that identity 'is a continuing piece of work, constructed in relation to the other, in conversation with the other, and, in the best of all possible worlds, in communion with the other' (p. 140). Cummins (2003) supports the same view: student-teacher interactions communicate to students' messages concerning their identity—who they are in their teacher's eyes and who they are capable of becoming. According to this view, empowering students becomes central to the learning process. In fact, this is the perspective espoused by Apple (1999): the construction of identity should be considered in terms of social relationships that lead to empowerment. In Wenger's (1998) work, the central idea is that identities are constructed 'in lived experience of engagement in practice' (p. 151). For him the role of language, although important, cannot account for the construction of identities. Given that a key element of his work is the notion of full participation in a community of practice (in order for people to create meaning), the construction of identities is viewed in relation to these communities.

What is not acknowledged explicitly by Wenger (1998) and also by Gallas (1997), Cummins (2003), and Apple (1999) is the role of the actual object of study in the process of identity construction. The awareness of the significance of the object of study (see Chap. 6), which can also help students to change their outlook on the world, may also be considered an important factor in the process of identity building (Hadzigeorgiou, 2012; Wong, Pugh, & Dewey Ideas Group at Michigan State University, 2001).

It deserves to be noted that the emotional significance of scientific ideas can be linked to the process of identity building. Why? If an awareness of the significance of an idea can result in a change of students' outlook on the world, then a change in the way students perceive themselves is also a possibility. This change of perception can facilitate the envisioning of possible identities, an idea that is also noted by Wong et al. (2001). In linking the process of identity building to the subject matter of science, they argue as follows:

*Powerful subject matter ideas create anticipations about a way of being in the world, and that way of the world includes not only an image of the world, but also an image of the student in that world.... As many biographies and auto-biographies reveal, an important part of scientists' identity is that ideas hold a special sway on them. They are motivated to continue to be the kind of people who experience the beauty and drama of science ideas.* (Wong et al., 2001, p. 335)

Although there is a difference between scientists and students (e.g. difference in motives, conceptual frameworks), change of perception can take place even in the case of students, both at the elementary and high school levels, provided that teachers use an 'aesthetic pedagogy' (Pugh, 2011; Pugh & Girod, 2007; see last section in this chapter), or they try to evoke a sense of wonder (Hadzigeorgiou, 2012; see Chap. 6 for such a change of perception).

In considering though the notion of identity building, another question needs to be raised: is science learning a possibility only for those who envision, for some reason, a career in science and engineering? According to Head (1997), those who make the choice to study science are those who resolve to be scientists from an early age. This ‘resolution’, of course, is supported by the view that personal identity and understanding are intricately linked (Gallagher, 1992, pp. 156–168; Godon, 2004): what one can understand is directly related to ‘the totality of one’s self-understanding and it is in that context that its significance gets decided’ (Godon, p. 590). This is an important message, since it points to the close relationship between identity, understanding, and learning. However, Marcia’s (1988) work on identity statuses (see also Kroger, 1996)—which are defined in terms of the dimensions of exploration and commitment—makes one consider not only the statuses of ‘identity achieved’ (commitment to an identity has been made) and ‘identity foreclosed’ (adoption of parental values) but also those of ‘identity diffused’ (no commitment to any life options has been made) and ‘moratorium’ (failure to see the importance of choosing one option over another). Is involvement with science an ‘impossibility’ for those students who have a diffused identity or for those who are in a moratorium? This question is imperative and points to the exploration of ways to encourage involvement with science, even when a commitment to becoming a scientist has not been made.

Two approaches, as research has shown, can be effective: the cognitive conflict approach, which can help evoke a sense of wonder (see Chap. 6), and the so-called aesthetic approach, which can provide students with opportunities for aesthetic experiences. Both approaches can encourage involvement with science, particularly with science content knowledge. The fact that there is some empirical evidence to support the view that an aesthetic experience, through students’ imaginative engagement with science content knowledge, can lead to identity options, and more specifically to the possibility of considering a career in science and technology (Hadzigeorgiou & Garganourakis, 2010), should certainly be considered. But what is really an ‘aesthetic experience’? Before this notion is discussed, the role of cognitive disequilibrium and cognitive conflict in the process of engagement, as was said, deserves particular attention.

## 2.2 Engagement Through Cognitive Disequilibrium

This idea of cognitive disequilibrium is central to the Piagetian epistemology. In Piaget’s (1977) most recent work, it is disequilibrium that produces the driving force of thinking and hence cognitive development. This disequilibrium occurs when there are contradictions between one’s expectations about an event or about the behaviour of an object and the actual results of one’s actions. For example, a child might believe, and therefore expect, that an orange will fall faster than a peanut, if they are both left to fall simultaneously from the same height to the ground. A simple demonstration provides a first-hand contradiction of this, since both the

orange and the peanut reach the ground simultaneously. It is this disturbance of a prior knowledge system and ‘the dissatisfaction with existing conceptions’, as Posner, Strike, Hewson, and Gertzog (1982, p. 214) had pointed out, that will lead to the construction of new knowledge. According to Glasersfeld (1989, p. 128):

*The learning theory that emerges from Piaget’s work can be summarized by saying that cognitive change and learning take place when a scheme, instead of producing the expected result, leads to perturbation, and perturbation, in turn, leads to accommodation that establishes a new equilibrium.*

Over the last three decades, this idea of disequilibrium has proved very fruitful in the area of science education, especially in physics education, since it was found to be a good strategy to challenge students’ misconceptions (Duit & Treagust, 2003; Treagust & Duit, 2008; Hadzigeorgiou, 1999; Hadzigeorgiou & Schulz, 2014). Situations causing confusion through perturbations of existing knowledge enable students to become aware of obstacles to be overcome in order for these situations to be understood. Discrepant events appear to be a good starting point in this strategy. These events can be introduced through (Hadzigeorgiou, 1999):

- Concrete (hands-on) activities (e.g. pouring water into a glass tumbler and seeing a coin at the bottom of the tumbler disappears, dropping objects of different weight from the same height to the floor and observing that they hit the floor simultaneously)
- Computer simulation (e.g. observing that an object can move in a straight line with constant speed even when no net force is acting on it)
- Questions that make students aware of explicit verbal discrepancies (e.g. if warm air rises, how come it is cold on a mountain top? If stars fall, why is the sky not empty after some time?)

Popper’s (1972) argument that ‘the vital first step towards understanding a theory is to understand the problem situation in which it arises’ (p. 182) is in line with the idea of ‘obstacle overcoming’ and provides food for thought for science teachers and science educators. According to Popper, it is not just the historical context that is crucial for understanding a science concept or idea, but the problem, the obstacle, that the scientists of the past faced and which they had to overcome in order to explain certain phenomena.

In the context of science education, engagement with science can also be identified with students’ awareness of obstacles or problems. Indeed, according to Dewey (1998), as was discussed in the previous chapter, consciousness of an obstacle is the source of reflective thought, and it is this consciousness that makes one feel perplexed, confused, or in doubt. Thus, in light of what Dewey said, a student, for example, trying to calculate the value of the specific heat capacity of a substance, or the magnitude of a force required to accelerate an airplane, experiences neither confusion nor doubt. In other words, the calculation of the specific heat capacity or the magnitude of the accelerating force cannot be sources of reflective thinking if there is not an awareness on the student’s part of an obstacle to be overcome, unless, of course, such an obstacle refers to the formula or the procedure to be followed, in



order for the calculations to be successfully made. On the other hand, a student trying to understand how a piece of pizza that did not feel so hot did burn his/her mouth, or how a soldier, according to a newspaper article, was electrocuted by touching a metal pole, may very well be perplexed and confused, since she or he cannot understand how these situations work. Thus cognitive disequilibrium is central to the process of involvement with science.

But although cognitive disequilibrium, as the initiator and the driving force of thinking, is of paramount importance, it is not the only 'key factor' involved in the teaching and learning of science. It is true, as was pointed out above, that instructional models developed over the last three decades placed a great emphasis on students' prior ideas, their elicitation, and restructuring (Driver & Oldham, 1986; Driver, Asoko, Leach, Mortimer, & Scott, 1994; see also Schulz, 2009). However, two major problems appear to emerge from this emphasis on the notions of disequilibrium/cognitive conflict and restructuring/conceptual change: one practical and one theoretical. The practical problem is about whether science learning can be based exclusively on perplexity and confusion. If everything that is to be learned were presented in a confusion-and-perplexity fashion, then many topics could very well be left out.

Using discrepant events, as a starting point of instruction, seems to be a good way to facilitate student involvement. Indeed the challenge of fundamental beliefs (e.g. heavier bodies fall faster than lighter ones, cold flows from cold to hot bodies, there is a net force in the direction of a body's straight line motion) produces confusion and perplexity, but what about topics like light interference patterns, crystal formation, the uncertainty principle, black holes, electric current and resistors, and bonding and chemical reactions? Certainly the practical problem seems to be resolved once we introduce all topics through discrepant events. But, until we develop curricula based solely on disequilibrium, we cannot accept the view that only cognitive conflict leading to conceptual change will lead to science learning (Hadzigeorgiou, 1999; see also Limon, 2001, Pugh & Girod, 2007).

In regard to the theoretical problem, this refers to the fact that the conceptual change approach per se has been considered too narrow. Why? This approach has been based mainly on three assumptions: First, 'learning is a rational activity', and therefore we should 'focus attention on what learning is, not what learning depends on' (Posner et al., 1982, p. 212). Second, 'ontogenetic change in an individual's learning is analogous to the nature of change in scientific paradigms' (Pintrich, Marx & Boyle, 1993, p. 169). And third, 'all concepts regardless of their origin and source are evaluated by the standards of science' (Cobern, 1996, p. 582).

These assumptions, of course, have been criticized (see Hadzigeorgiou, 2005b; Hadzigeorgiou & Konsolas, 2001; Limon, 2001; Schulz, 2009, 2014). In fact, Strike and Posner (1992), the two of the four science educators who proposed the conceptual change model (which was based on the idea that the primary goal of school science education was to help students change their conceptual ecology, by replacing a set of concepts with another set, incompatible with the first) in acknowledging the role of intuition, emotions, motives, and goals in the process of conceptual change, point out that 'the idea of a conceptual ecology [...] needs to be larger than the epistemological factors suggested by the history and philosophy of science'

(p. 162). Apparently, motivational and generally affective factors, which were downplayed by constructivist/conceptual change models (see Treagust & Duit, 2008), need to be seriously considered by science teachers and science educators, if they are to encourage involvement and facilitate learning.

And yet, over the past two decades, science education has been dominated by such notions as conceptual change and science inquiry, in line with a constructivist perspective on teaching and learning science. Pugh and Girod (2007) call these notions ‘dominant paradigms’ that have shaped the current landscape of science education and propose art and aesthetics as potential paradigms to join the ranks of the dominant ones. The idea of aesthetics in science education may seem at odds with the other dominant ideas of conceptual change and inquiry, but it is not. In fact it is complementary, but, at the same time, central to both inquiry and conceptual change (see Chaps. 6 and 7).

*Science education is still largely focused around standards, conceptual change, and inquiry. These are some of the dominant paradigms that shape current science education pedagogy. What if art and aesthetics were to join the ranks of these dominant paradigms? (Pugh & Girod, 2007, p. 10)*

What must be recognized, with regard to the process of cognitive conflict per se, is that it does make students intellectually curious about what is really going on in the situation that produces conflict. But what also should be recognized is that intellectual engagement may very well be fostered through an ‘aesthetic awareness’, that is, through an awareness of the aesthetic dimension of science (i.e. awareness of the mysterious and also of the beauty of science). Bachelard’s idea, that ‘all knowledge is the answer to a question’ (cited in Gil-Perez & Carrascossa-Alis, 1994, p. 307), is certainly a valid one. But what kind of questions are we talking about? Wonderment questions, as empirical evidence suggests, do foster thinking (Chin, 2007; Chin, Brown, & Bruce, 2002; Hadzigeorgiou, 2012), but their source is not only discrepant events that produce cognitive disequilibrium, thus making students aware that their knowledge is incomplete or erroneous. Their source can be also found in mysteries and paradoxes and in the experience of wonder (see Chap. 6). In other words, Bachelard’s point is well taken, provided the question to be answered does not have its source only in cognitive disequilibrium but also in the experience of mystery and wonder, for it should be noted that wonderment questions can be raised through one’s aesthetic appreciation of nature and its phenomena. Such an appreciation has been crucial in scientific progress (see section on imagination and the nature of science in Chap. 1). In the case, for example, of some students who wondered about how Newton thought about the law of action and reaction and who expressed an admiration for Newton’s genius, one can clearly see that a wonderment question can have an aesthetic dimension too (see Chap. 6).

Indeed, it could be argued that everything around human beings can be taken to be a mystery and a source of wonder that capture their imagination and makes them think (Hadzigeorgiou, 1999). Although growth in scientific knowledge is due in large part to the identification and subsequent solution of a problem, as Popper (1972) argued, science, as a form of inquiry, was developed not because all problems produced disequilibrium and confusion (i.e. cognitive conflict) but rather because human

beings have an inborn bewildered curiosity and a sense of wonder, which is evoked by a sense of mystery (Hadzigeorgiou & Schulz, 2014). Thus, the desire for explanations and understanding cannot be seen as the sole result of cognitive conflict. And it is for this reason that the possibility of providing students with opportunities for aesthetic experiences is quite crucial.

## 2.3 The Notion of Aesthetic Experience

The notion of experience is quite common, not only in everyday language but also in the language of education. We talk, for example, about experiential learning, which is distinguished from a learning experience in general, as well as about students' experiential repertoire and educative experiences. And we all know that although students have many experiences, in and out school, these are not necessarily educative. More often than not, students' experiences cannot even be called 'learning experiences'. Given that an 'experience' is the unique outcome of a student's interaction with his/her environment—therefore the notion of experience should not be confused with that of activity—participation in a planned activity does not necessarily result in learning. The reason is that a student's experience depends upon what Dewey (1938) called the 'internal' and the 'external' conditions. The former refers to a student's interest, motivation, and prior knowledge, while the latter refers to the total social and physical set-up of the classroom and also to what the teacher does and says. It is evident that an interaction of these two conditions can have diverse outcomes for the students, despite the fact that they have participated in the same activity. However, even if an experience can result in some kind of learning, there is still a question concerning the quality of that experience.

It is for this very reason that Dewey (1934) proposed the term 'aesthetic experience'. According to him, there is a difference between an ordinary experience and an aesthetic experience. The latter is a holistic and fulfilled experience, in the sense that feelings, thoughts, and actions form a unified whole.<sup>2</sup> The role of the imagination in such a holistic experience is also acknowledged by Dewey: 'Esthetic experience is imaginative [...] all conscious experience has of necessity some degree of imaginative quality (p. 272).

What must be pointed out is that while the senses play an important role in an aesthetic experience (e.g. in the case of an artistic creation, in the case of observing a natural phenomenon), their role is not to be restricted solely to certain sense qualities, such as colour, odour, or texture, as is the case with traditional empiricism (i.e. Hume's empiricism). For Dewey (1934), it is the meaning attached to these sense qualities and their integration into a unified whole that determines whether or not an

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<sup>2</sup> According to Dewey (1934), the origins of an aesthetic experience are both artistic/creative experiences (e.g. those of artists) and everyday, commonplace experience. Therefore the students' experience in school or outside of school can also be aesthetic experiences (see also Alexander, 1987, for an analysis of Dewey's idea of aesthetic experience and a better understanding of his aesthetic philosophy).

experience will be an aesthetic experience. In other words, unless one creates meaning from what one abstracts from current experience, on the basis of one's values and past experiences, one cannot have an aesthetic experience.

Scholarly work on aesthetic experience points to such descriptions of it as 'vital experience' (Aguirre 2004, p. 259), 'transformative experience' (Pugh, 2011, p. 107), 'compelling and dramatic' experience (Girod et al., 2003, p. 578), and 'powerful' experience (Wong, 2002). However, a distinctive feature of an aesthetic experience is that it is 'consummatory', in the sense that there is a completion and not a cessation of the experience. It is this consummation, at the end of the aesthetic experience, which brings a kind of satisfaction and fulfilment. The following excerpt from Dewey's *Art as Experience* is illustrative of what an aesthetic experience is:

*Oftentimes, however, the experience had is inchoate. Things are experienced but not in such a way that they are composed into an experience. There is distraction and dispersion; what we observe and what we think, what we desire and what we get, are at odds with each other [...] In contrast with such experience, we have an experience when the material experienced runs its course to fulfilment. Then and only then is it integrated within and demarcated in the general stream of experience from experiences. A piece of work is finished in away that is satisfactory; a problem receives its solution; a game is played through; a situation, whether that of eating a meal, playing a game of chess, carrying on a conversation. Writing a book, or taking part in a political campaign, is so rounded out that its close is a consummation and not a cessation. Such an experience is a whole and carries with it its own individualizing quality and self-sufficiency. It is an experience. (Dewey, 1934, pp. 36–37)*

The intense feeling of 'consummation' is related to that of 'anticipation'. As Dewey (1934) argued, consummation 'does not wait in consciousness for the whole undertaking to be finished. It is anticipated throughout and is recurrently savoured with special intensity' (p. 55). Thus, an aesthetic experience is dramatic. And like drama, 'it involves a build-up and resolution of anticipation that gives the experience its completeness and uniqueness' (Pugh & Girod, 2007, p.11). In education, apparently, it is desirable for students to have experiences that lead to consummation, not cessation. Although an aesthetic experience cannot be a pre-planned experience, some activities are more likely to provide opportunities for anticipation and consummation in the context of science education. Storytelling, for example, has the potential to create anticipation through the plot of a story<sup>3</sup> (see Chap. 4). Certain

<sup>3</sup>An excellent way to develop in students a sense of anticipation is through storytelling (see Chap. 4). We all know that we anticipate a good story, and in the case of school science education, an introduction is quite crucial. The following introduction played a catalytic role in creating anticipation for the Tesla story (Hadzigeorgiou, Klassen, & Froese-Klassen, 2012): *The following Saturday we are going to listen to a story about something that we take for granted, but which literally transformed our lives. In actual fact ever since, our world has not been the same. This 'something' is the electric current, which makes almost all of our home appliances work, which is used in industry and, generally, which changed completely the world about a century ago. No one would dare to imagine what our life and the world at large would be like without the use of electric current. Moreover, many of us are unaware of the fact that useable electric current was an idea of a man; a product of his legendary, extraordinary, even heroic qualities; and the victor of a long controversy and battle. This battle, known as the 'War of the Currents', was finally won by that man, in 1895, when, for the first time, he was successful in transmitting electrical power from Niagara Falls to Buffalo City, about 34 km away. That feat was*

immersion activities—especially those connecting science and art—can also provide students with opportunities to experience anticipation (see Chaps. 5, 6, and 7).

In the literature one can find a few approaches to the notion of ‘aesthetic experience’ (e.g. Girod et al., 2003; Jakobson & Wickman, 2008; Wickmann, 2006). Girod et al. have identified certain behaviours associated with the having of an aesthetic experience as follows:

- Trying to learn more about what has been taught in the classroom
- Thinking about it outside of the classroom
- Talking to other people about what has been taught
- Trying to see examples of the taught ideas in everyday life
- Seeing the world differently

For Girod et al. (2003), the students who demonstrated those behaviours, after a teaching intervention, developed an ‘aesthetic understanding’. The idea of seeing the world differently is also captured in what Pugh (2002, 2004, 2011) calls ‘transformative experience’,<sup>4</sup> whose qualities though are the same as those of ‘aesthetic understanding’. Indeed, the conception of transformative experience ‘as a learning episode in which a student acts on the subject matter by using it in everyday experience to more fully perceive some aspect of the world and finds meaning in doing so’ (Pugh, 2011, p. 111) is based upon Dewey’s (1934) theory of experience and more specifically upon the idea of engagement with content knowledge, which results in an expansion of one’s perception. And this expansion of perception, as a result of learning, is the first step towards seeing the world differently.

Even though a number of philosophers and educators have defended significant learning as a transformation of one’s outlook (see Hadzigeorgiou & Schulz, 2014), and therefore such a learning outcome should not be linked exclusively to Dewey’s aesthetic theory (which is the basis for the aesthetic teaching/learning approaches to school science education), seeing the world differently can be facilitated by aesthetic approaches. A review of the studies on aesthetic approaches to science education (see later in this chapter) does show that the notions of ‘aesthetic understanding’, ‘aesthetic experience’, and ‘transformative experience’ have identical or similar characteristics. The main difference between aesthetic approaches can be found in

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*something unthinkable, even unimaginable, at that time and that’s why it was covered by the world press and that man was praised as a hero worldwide. That man was Nikola Tesla, who, according to Life magazine’s special issue (September 1997), is considered among the 100 most famous people of the millennium. Although current electricity was not a new idea at the time of Tesla, the transmission of current electricity over such a distance, and at that time, was a heroic achievement, which is directly associated with Tesla’s extraordinary mind and especially his passion for, and even obsession with, a particular kind of current that is called alternating current (AC) (see Appendix A for the Tesla story itself).*

<sup>4</sup>Pugh (2011) explains why we need a concept like ‘transformative experience’: ‘We do have concepts like ‘meaningful’ or ‘authentic’ learning, but such constructs are vague and do not specifically target the *consequences of school learning on everyday experience*. In addition, we have constructs that represent discrete components of this phenomenon, including the constructs of transfer, conceptual change, task value, and individual interest. I propose transformative experience as a composite at the individual level that integrates these discrete components and represents the phenomenon of school learning transforming everyday experience’ (p.107).

the way one goes about to find out whether an experience is aesthetic or transformative.

Wickmann (2006), for example, focused on, and studied, the way students express themselves during science activities (rather than on learning outcomes after an intervention). In pointing out that ‘learning science from the primary school to the tertiary level is in necessary and inseparable ways dependent on aesthetic experience’ (p.145), he found that an aesthetic experience can play four different roles in the process of learning science;

- It helps students learn how to act and work in the science class.
- It helps students to connect their everyday/informal experiences with the classroom science experiences.
- It helps students use aesthetic language effectively in order to convey experiences over time by the use of aesthetic words.
- It is integral to the facts and logic/reason of science.

An important notion for Wickmann (2006) is that of ‘aesthetic judgements’, which he defines 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. (Wickmann, 2006, p. 9)*

By focusing on the aesthetic judgements and the language used, as students react and communicate their feelings and emotions about the experiences of phenomena, Wickmann (2006) studied an aesthetic experience from both a positive and negative perspective. He used such ‘binary opposites’ (see Egan, 1997, 2005) like beautiful/ugly and pleasure/displeasure in order to analyse students’ feelings, since the latter influence children’s approach to learning science. It is apparent that Wickmann acknowledges the fact that engagement in science has two dimensions, an emotional and a cognitive, and that the two are inextricably linked (Hadzigeorgiou & Stivaktakis, 2008).

Jakobson and Wickman (2008), in line with Wickmann’s (2006) approach, studied elementary school children’s aesthetic experiences, that is, their experiences related to what they found beautiful/ugly and also pleasing/displeasing when learning science. In studying what young children liked and disliked, they found that children’s judgements are not trivial utterances but of great significance in the situation in which they are uttered. These judgements are important for learning not only science ideas but also the normative aspects of doing science and also important for engagement with science. Indeed, given that the idea of beauty and what counts as beautiful are rooted in one’s worldview, aesthetic judgements and more specifically judgements regarding personal tastes (e.g. beauty/ugliness, liking/disliking, nice/disgusting) which are involved in many science activities (e.g. an arrangement of some things during an experiment, dissecting an earthworm) determine the extent to which one becomes involved with science (Hadzigeorgiou, 2005b). In short, aesthetic judgements can be seen as a tool to study interest in

science, which (interest in science), according to Klassen and Froese-Klassen (2014b), deserves more attention by mainstream science education. As Jakobson and Wickman pointed out ‘we should look closer at the possibility that interest in school science does not come as a lightning flash, but is slowly learnt in the numerous aesthetic encounters of science class’. (pp. 62–62)

Milne (2010), on the other hand, attempted to classify aesthetic experiences on the basis of their potential to generate a sense of awe and wonder and therefore interest in science. His list includes the following types of experiences:

- *Spiritual*: Experiences from both a religious and secular perspective  
Indicators: (a) Statements or feelings expressed when looking at stars and appreciating nature. (b) Direct reference to God or a creator
- *Utilitarian*: Experiences motivated through need or problem solving  
Indicator: Expressions or feelings communicated when faced with and overcoming challenges associated with problem solving
- *Fashion/marketing*: Experiences in the context of fashion/marketing  
Indicator: Expressions or feelings expressed when affected by such context
- *Value/respect*: Experiences associated with an appreciation of the power of nature or the power of position  
Indicators: Expressions or feelings expressed when confronted with (a) the awesome power of nature (e.g. as in tsunamis, earthquakes) and (b) the awesome influence of people in a certain position (e.g. as in the case of the Pope or a great athlete)
- *Beauty*: Experiences resulting from an appreciation of natural form and structure of nature  
Indicator: Expression or feelings expressed as one responds to interactions or close encounters with natural entities (e.g. stars, flowers, rocks)
- *Mathematical*: Experiences resulting from an appreciation of the natural patterns of nature both in form as for beauty and abstraction for number  
Indicators: 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 that result in an interest over time  
Indicator: Attachment and/or reaction to both pleasurable and non-pleasurable experiences
- *Curiosity*: Personal experiences that result in pure curiosity  
Indicator: Expression of curiosity in order to understand the world

From the aforementioned approaches, it becomes apparent that an aesthetic experience requires more than what the constructivist approach to teaching and learning science prescribes. This is extremely crucial to stress, given the argument that ‘the aesthetic dimension of knowledge is more likely to be appreciated, if knowledge is seen as something that is constructed and not as something that we

merely discover or find' (Eisner (1985, p. 8). But the appreciation of the aesthetic dimension of scientific knowledge—for example, when one perceives beauty in scientific knowledge (see Chaps. 5 and 7)—is more realistic in the context of professional science rather than school science education. In light of this difference between scientists and school students, one should be careful not to conflate the aesthetic dimension of scientific knowledge with the having of an aesthetic experience, even though the former can sometimes lead to an aesthetic experience in the context of school science. In any case, what should be clear at this point is that an aesthetic experience is not an ordinary educational experience, and a constructivist approach to teaching and learning science does not guarantee the having of an aesthetic experience. In short, it is not easy for a student to have an aesthetic experience, no matter how 'constructivist' such an experience may have been.

For Dahlin (2001), who recommends attention to 'the aesthetic dimension of knowledge formation' (p. 130), aesthetic is 'a point of view which cultivates a careful and exact attention to all the qualities inherent in sense experience' or 'an approach to natural phenomena' which (approach) 'would not merely be to appreciate their beauty, but also understand them' (p.130). Capra's (1977) experience, as described at the beginning of this chapter, is based on 'exact attention to all the qualities inherent in sense experience', and therefore it can be called an aesthetic experience. Thus, an aesthetic experience results from a holistic experience, and this requires a phenomenological, not simply constructivist, approach to teaching and learning science (see Hadzigeorgiou & Schulz, 2014; Østergaard, Dahlin, & Hugo, 2008). The reason is that a constructivist approach does not necessarily require holistic experiences (in which emotions, imagination, reason, and action are united, and there is involvement with the object of study per se). Indeed, an important distinction between a constructivist and a phenomenological approach to learning should be pointed out, whereas the former is based upon the purely cognitive aspect of the construction of knowledge, 'phenomenology has a stronger emphasis on the precognitive phase, including the roles of sensing and feeling as different from purely conceptual cognition' (Østergaard et al., 2008, p. 98).

I believe that, in the context of science education, it is preferable to say that an aesthetic experience presupposes a phenomenological/aesthetic approach to science, that is, a holistic approach, which, on the one hand, places primacy upon 'lived experience' and not simply upon sense experience (e.g. listening, observing) and, on the other, considers the aesthetic dimension of scientific knowledge (Hadzigeorgiou & Schulz, 2014). In other words, such an approach includes sense experience, emotions, somatic reason, and also the appreciation of the beauty of science (especially the role that aesthetic perception plays in the construction of knowledge). Thus, it provides students with opportunities for 'careful and exact attention to *all the qualities* inherent in sense experience' (Dahlin, 2001, p. 454, my emphasis).

By the same token, an aesthetic experience in science is not necessarily a 'wow experience'. The 'wow factor' (Feasey, 2005) in school science is certainly important, but it does not necessarily lead to an aesthetic experience, unless the characteristics of an aesthetic experience are present. Put simply, in an aesthetic experience,



it is not only the emotional but also the cognitive dimension of involvement that needs to be present (see Chap. 6).

Perhaps the most important educational outcome associated with an aesthetic experience is the change of one's outlook on the world. This means that one sees the world differently as a result of an aesthetic experience. Such change or transformation as a result of learning goes beyond an 'artistic expansion of perception' (i.e. seeing details and nuances) even though the latter can often lead to the former. When Feynman said that the world looks beautiful after one learns science, he made reference to one's ability to see the world differently.

It is interesting to note that the need for an experience, which makes students see the world differently and also apply science in their everyday life and beyond their classroom and school, had been pointed out by both Barnes (1987), who stressed the importance of 'action knowledge', and R. S. Peters (1966), who argued for the development of 'cognitive perspective'.<sup>5</sup> Barnes differentiated between 'action knowledge' and 'school knowledge'—the former representing knowledge that is applied in one's everyday life and makes one see objects and phenomena differently—while Peters thought that knowledge and understanding should not be inert, but part of one's everyday life, and should allow one to see the place of knowledge 'in a coherent pattern of life' (Peters, 1966, p. 45). Thus, while there is no mention of aesthetics, or aesthetic experience, in Barnes' and Peters' arguments about school learning and education, their views do express a transformative pedagogy (i.e. learning that can be applied to everyday contexts and learning that produces a change in perception).

The following section provides empirical evidence for aesthetic experiences in real classroom settings. Although such evidence is still limited, it is nonetheless encouraging, as it shows that, for some students, the having of an aesthetic experience is indeed a possibility.

## 2.4 What the Research Shows

The discussion thus far begs one question: how realistic is the having of an aesthetic experience in classroom settings? Notwithstanding the methodological difficulties inherent in the process of conceptualizing and evaluating an aesthetic experience, due to the conceptual complexity of the latter (see Pugh, 2011), the evidence so far, albeit limited, is quite encouraging. Intervention studies with both elementary and

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<sup>5</sup>It is unfortunate that the term 'cognitive perspective', which Peters (1966) used as one of the criteria by which to judge the educated person, might lead one to take it as representing a limited view of knowledge. But if cognitive perspective is about the ability of the learner to see the place of knowledge 'in a coherent pattern of life', then cognitive perspective is closely related to emotions, aesthetics, and ethical conduct. Therefore it is a holistic notion. Scheffler (1996), in fact, has pointed out that 'the notion of cognitive perspective is related to the idea of wholeness' (p. 84).

junior high school students in the USA demonstrate that teaching for aesthetic/transformational experiences has a positive effect on science learning.

Girod and Wong (2002), in a case study of three grade 4 students learning about rocks, found that one of the students did have an aesthetic experience, given that she created a 'rock book', which, in fact, was not part of any class assignment. She reported during an interview that she thought about rocks differently than she did before the lesson and that whenever she had nothing to do, she looked at a rock and then try to tell its story (i.e. what its name is, where it came from, where it formed). During this interview she also said that she could imagine herself being a geologist, which is evidence that her learning experience made her consider an identity option.

Pugh (2004) found similar results in a case study of two grade 7 students, who were learning about Newton's laws of motion. One of the students became involved with the lesson and then began to associate everyday phenomena of motion with Newton's laws of motion. An example illustrating the fact that Newton's laws became part of his life is when he was observing his young niece running across the recently mopped floor and not being able to stop till the door acted on her and stopped her. This example and others that this student cited show the influence that the learning experience had on him. His learning experience was transformational in the sense that he began to look at everyday phenomena involving force and motion differently (i.e. through a scientific lens) and also he began to look at himself differently (i.e. he described himself as a science person).

Experimental studies by Girod et al. (2003, 2010), and Pugh (2002) also produced evidence that teaching for aesthetic understanding can have a significant impact on students. In regard to the study by Girod et al. (2003), the sample was two 4th grade classes (ages 9 and 10 and 28 students in each class). One of the classes was taught for conceptual understanding (control group), while the other class for aesthetic understanding (treatment group), through discourse emphasizing engagement with science content knowledge. This science content was taught over a period of 10 weeks and concerned geological topics such as fossils, minerals, rocks, weathering and erosion, as well as rocks, and volcanology. The assessment of aesthetic understanding was made possible through a survey that included a story (vignette) about a student who learned about friction and found it to be powerful and important, and a questionnaire. First students in both classes were read this vignette and then asked to respond to questions, which investigated the degree to which they have had experiences similar to the experience of the student described in the story. Each question related to some element of aesthetic understanding, such as the perceived transformation of person and world, learning that brings unification or coherence to science ideas and phenomena, and the dramatic nature of learning in this way. Girod et al. (2003) found a statistically significant difference between the groups, with students in the experimental group reporting greater levels of engagement. The results show that 'for the most part, students in the experimental classroom experienced clear, and in some cases, profound progress toward the three conditions of aesthetic understanding' (p. 583).

As regards the intervention study by Girod et al. (2010), two 5th grade classes were used over a whole school year (9 months)—the experimental group was taught

for aesthetic understanding and the control group was taught in a traditional manner, emphasizing the cognitive aspects of the learning process. The science content that was covered involved three units on weather, erosion, and matter. The researchers looked at levels of interest in science, efficacy beliefs (about themselves as learners) and identity beliefs (about themselves as ‘science-type’ people), levels of conceptual understanding, retention of conceptual understanding 1 month after instruction, and also the possibility of acting differently in the world as a result of new learning. The differences between the groups were small, but nonetheless statistically significant (even though the differences between the two classes, control class and treatment class, judged from the scores on pretests for each of the factors (interest, efficacy beliefs, and identity beliefs) were very small). Girod et al. found that the experimental group displayed greater learning at both the follow-up and the posttest assessment, but with a greater effect occurring at the follow-up assessment. The main differences between the students of the two groups in regard to conceptual understanding—both immediately after instruction and in the delayed (after 1 month) posttest condition—were that students who were taught for aesthetic/transformative experience appeared to view the world differently and continued to investigate the world using ideas learned in class. On the other hand, the students from the control class were more focused on science terminology and sought to learn and apply new knowledge not because they found it interesting but because ‘it made them feel smart’.

Similar positive results have also been reported by Pugh (2002), who conducted an intervention study with two high school biology classes. Both classes were taught a unit on animal adaptation and natural selection. One class (the experimental group) was taught for aesthetic/transformative experiences. In the other class (the control group), the inquiry model was used. The results showed a statistically significant difference between the two groups, with a greater percentage of students in the experimental group displaying engagement in transformative experiences. For example, one student said that learning about animals stimulated an interest to learn more about them, while another student reported that he applied the ideas of adaptation and evolution many times in his everyday life and whenever he saw an animal he wondered if it related to him in some way. And he was aware that the concept of adaptation made him try to understand more about it. Pugh reports that the students from the experimental group displayed greater learning immediately after intervention but not at the posttest compared to students from the control group.

Pugh et al. (2010a), on the other hand, in their study with high school students, found that most students in their sample did not show any evidence of deep engagement with science, which is a prerequisite for an aesthetic/transformative experience. These students exhibited, as Pugh et al. say, low levels of transformative experience. However—and this is important to stress—‘those students who strongly identified with science and who endorsed a mastery goal orientation were more likely to report engagement in higher levels of transformative experience’ (p. 1). Pugh et al. also found that high levels of engagement in transformative experience were associated (a) with conceptual change regarding natural selection but not inheritance at both the follow-up and the delayed posttests and (b) transfer at the

follow-up assessment. Pugh et al. proposed that students with a mastery orientation would be more likely to undergo transformative experiences than those with a performance orientation.

Even though the aforementioned studies did not assess conceptual change, it is very likely that those students who had an aesthetic/transformational experience changed their conceptual framework too. However, it is also very likely that students (from the experimental or the control group) who experienced conceptual change did not have an aesthetic experience. Pugh, Linnenbrink-Garcia, Koskey, Stewart, and Manzey (2010b) compared the effects of implementing the TTES (Teaching for Transformational Experience in Science) model in combination with a conceptual change model with the effects of implementing the conceptual change model alone. The teacher created three treatment groups. One was the control group (2 classes, 40 students), while the other two groups (2 classes, 42 students and 2 classes, 44 students) would receive two different instructional treatments aiming at conceptual change and transformational experience, respectively. The results obtained through a comparative analysis of the three instructional conditions show that the combined TTES and conceptual change models fostered student engagement and learning, compared with both the control instructional condition and the conceptual change condition. The TTES model was found to foster transformational engagement and support transfer of knowledge and conceptual change (when combined with the conceptual change model). Pugh et al. (2010b) report that students who were taught for transformational experience displayed greater transformational engagement in class but did not report a higher level of transformational experiences. In the case of regular-level students, the combination of TTES and conceptual change models fostered greater change in basic knowledge, while the TTES model helped them display more enduring transfer. In the case of honours-level students, the combination of TTES and conceptual change models helped with inducing greater conceptual change, but not greater transfer.

In the context of Swedish schools, Jakobson and Wickman (2008) selected a variety of schools (e.g. a big city school, a school in a rural area, and three medium-sized town schools) in order to study elementary school children's (ages 6–10) aesthetic judgements during hands-on inquiry activities in physics, chemistry, biology, and earth science. They recorded children's talk in the context of nine units (e.g. changes/the transformation of matter, solids and liquids, electric circuits, mixing and separating, buds, shadows, and soil). The results showed that children experienced not only anticipation but also consummation (i.e. feelings experienced when a science activity does not simply end but instead is brought to fulfilment) and that through aesthetic judgements, the children talked about their own place in their science class and whether they belonged there.

However, what should be pointed out here is that imaginative engagement with science content knowledge can also lead to an aesthetic/transformational experience. According to empirical evidence from three studies in Greece with junior and senior high school students (Hadzigeorgiou, 2012; Hadzigeorgiou et al., 2012; Hadzigeorgiou & Garganourakis, 2010), the development of romantic understanding (see Chap. 3) and the experience of a sense of wonder (see Chap. 6) fostered an

aesthetic/transformative experience. Such a claim can be based on several findings, such as (a) students spending time outside the school to search for information regarding ideas and phenomena that they found mysterious, amazing, and astonishing; (b) students spending time to make journal entries during their free time; (c) their perception regarding science ideas, natural entities, and phenomena as well as their view of science as a school subject that changed as a result of learning science; and (d) the possibility to consider a career in a science-related field (e.g. electrical engineering). Even though these findings are based upon data that came from observation and students' journal entries, they are nonetheless indicators of an aesthetic/transformative experience. Even if such a claim is considered too bold, there is evidence for deeper involvement with science, which, in turn, helped some students change their perception of the natural world and of science as a school subject (see Chap. 6).

The studies that were cited in this section provide evidence that an aesthetic experience is not simply an abstract concept or an ideal situation, perhaps necessary as a standard for judging the quality of students' everyday educational experiences. This is, of course, important, but the message from the aforementioned studies is that aesthetic experience is indeed a possibility, at least for some students, and that the having of an aesthetic experience determines interest and involvement with science. What must be stressed, therefore, is that even though such an experience represents the ideal educational experience, and its evaluation is not quite straightforward,<sup>6</sup> neither the possibility on students' part to actually have such an experience nor the effort on teachers' part to foster it should be downplayed or dismissed.

## 2.5 Implications for Science Education

The notion of aesthetic experience has important implications on school science education. The first, and perhaps the most important one, I believe, is students' emotional involvement with science, particularly its ideas. The reason is that such an emotional involvement can help bring science outside the school classroom (Hadzigeorgiou, 2005a; Hadzigeorgiou & Stivaktakis, 2008; Pugh, 2004). As Pugh and Girod (2007) pointed out, 'As science educators, we often obsess over misconceptions but fail to ask whether students ever apply their 'correct' conceptions outside of school and use them to have aesthetic experiences in the world' (p. 10).

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<sup>6</sup>If a student reports that she or he had a transformative experience (i.e. by saying that the lesson made her or him find a science topic interesting or intriguing and that she or he experienced change in the way she or he perceives reality and science or by saying yes, when she or he is asked, to all the questions regarding the criteria whereby one judges a transformative experience), it cannot by itself guarantee transformative experience. Multiple data are certainly needed, and inferences must be carefully drawn.

But in order for students to become emotionally involved with science and apply their conceptions outside of school, teacher awareness of the centrality of ideas in the process of meaning making is imperative. It has been pointed out that

*One of the major failures of our present educational efforts is that so many schools leavers have little sense of what ideas are or how to use them and control them [...] The development and manipulation of ideas are central to rationality, to romantic understanding, and to the Western intellectual tradition. (Egan, 1990, p. 225)*

Focusing on ideas as potential sources of wonder (see Chap. 6), as tools that help bring out the drama inherent in their conception and historical development, especially if presented through storytelling (see Chap. 4; see also Appendix A) or through dramatization (see Chap. 7), should be seen as the number one priority in curriculum planning. Ideas, such as electric current, force and motion, photosynthesis, light reflection, chemical valence, can be seen as curriculum items to be learned or as ideas that can have an impact upon one's life. Even though 'learning meaningfully' such ideas can be—as it has been—based upon their various interrelationships, as in a concept map (Novak & Gowin, 1984), one becomes aware of their emotional significance (and hence existential meaning) if one becomes aware of their relationship with human life, especially one's personal life (Hadzigeorgiou, 1997, 2005b; Hadzigeorgiou & Schulz, 2014).

Of course, the most important and practical, at the same time, implication of the notion of aesthetic experience regards the question about how a teacher can foster such an experience. What steps she or he can follow? What she or he can focus on in order to increase the possibilities for an aesthetic experience? Pugh and Girod's (2007) aesthetic pedagogy, based upon Dewey's notion of aesthetic experience, is worth considering in regard to what a teacher can do in her/his classroom. They recommend the following six guidelines:

- Crafting ideas out of concepts
- Restoring concepts to the experience in which they had their origin and significance
- Fostering anticipation and a vital, personal experiencing
- Using metaphors and 're-seeing' to expand perception
- Modelling a passion for the content
- Enculturating students into ways of valuing and experiencing science idea

These guidelines can indeed help one 'bring out' the emotional significance of science ideas and thus encourage deeper engagement with them. The task of crafting ideas, for example, which refers to the process whereby the curriculum content is transformed into a list of beautiful and powerful ideas, becomes 'something that is relished' (Girod et al., 2003, p. 579) and not just a list of concepts to be learned (e.g. the idea that we can use the same laws—contrary to what Aristotle and Mediaeval scholars believed—to study the motion of a water drop, a soccer ball, a dancer, an asteroid, and a distant planet). And because science ideas have their origins in human experience and are tied both to those who created and developed them and to the specific events that facilitated or even hindered their creation and

development, restoring concepts to the original experience can help bring out the drama that has been involved in the development of scientific knowledge.

*Take, for example, the idea of a heliocentric solar system. Long ago this was a frightening, provocative, even terrifying idea – one that forced students to think about the world and their place in it, very differently. Today, however, the notion of a heliocentrism is taken for granted as something always known or understood. Heliocentrism has lost its artistic power to shape our understanding in profound ways. The first step in teaching for aesthetic understanding is to recapture or reanimate existing content into the artful and compelling ideas they are (or were at one time).* (Girod et al., 2003, p. 579)

Anticipation also is quite important as students are prepared to feel the suspense, the excitement, even the drama inherent in science ideas. A project or an artistic/creative activity, in which students will participate, a story that will be told in the classroom, and even a brief introduction that imaginatively outlines the unit or the lesson can all help foster anticipation. As for the ability to see differently something as a result of learning, teachers can cultivate an artistic kind of perception—Girod et al. (2003) talk about ‘re-seeing’ as ‘an attempt to focus our perception on the nuance and detail of the world’ (Girod et al., pp. 579–580). They can also evoke a sense of wonder at and about the ideas of the lesson, by using metaphoric/poetic language, by pointing out to students’ unexpected relationships among phenomena and among ideas, and by revealing the mystery associated with science ideas and phenomena (see Chap. 6).

As regards the modelling of passion, it is imperative that teachers first feel the fun, the excitement, and the wonder of science before they attempt to make their students experience such feelings. They must show their students how the ideas of science have an impact on their own (teachers’) life. Thus passion for science and its ideas can motivate students to experience what their teacher has experienced.

It is apparent from the aforementioned guidelines that an aesthetic approach should not be conflated with a constructivist approach, as the former is more phenomenological.<sup>7</sup> On the other hand, constructivism’s main focus has been on the construction of knowledge per se, not on the quality of students’ experiences, which may also change the way they view learning and the world, and themselves.<sup>8</sup>

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<sup>7</sup>It should be noted that even though Dewey’s aesthetic philosophy (Dewey, 1934) is not explicitly phenomenological, its potential to make a contribution to the literature concerning the phenomenological approach to learning science needs to be acknowledged (Hadzigeorgiou & Schulz, 2014). One could talk, for example, about a ‘phenomenological/aesthetic’ approach to science as a holistic approach, which, on the one hand, places primacy upon ‘lived experience’ and not simply upon sense experience (e.g. listening, observing) and, on the other, considers the qualities of an aesthetic experience. In other words, such an approach includes sense experience, emotions, somatic reason, and also the appreciation of the beauty of science and its ideas (especially the role that aesthetic perception plays in the construction of knowledge). Thus, it provides students with opportunities for ‘careful and exact attention to *all the qualities* inherent in sense experience’ (Dahlin, 2001, p. 454, my emphasis).

<sup>8</sup>Both phenomenological and constructivist approaches are based on the notion of subjectivity, even though in the case of social constructivism, interactions between the individual and the social environment are central to developing knowledge and understanding. However, while in both constructivist and phenomenological learning, subjectivity plays a central role, in phenomenological

Wong's (2002) view that constructivist approaches with their emphasis on logico-mathematical thinking, self-regulated learning, and rational reflection may very well be an obstacle to the having of transformative experience, as such notions presuppose a dualism between students and their object of study. Wong's (2002) notion of 'opposite of control' provides food for thought, as an emphasis on conscious control in regard to learning (e.g. emphasis on metacognition) cannot foster an aesthetic/transformative experience: '[...] an excess of conscious control and self-awareness is more likely to obstruct rather than facilitate the having of transformative experiences' (Wong, 2002, p. 204).

Another important implication is to help students develop the ability to see what they normally do not see, that is, the ability to observe details and nuances, which, in turn, can help them view everyday objects and phenomena in new light. Hadzigeorgiou and Schulz (2014) recommend that science education reclaim the value of sense experience, which, according to the constructivist perspective, was considered the source of students' misconceptions and therefore an obstacle to learning. But if a change in students' outlook is considered an important instructional goal, then a 'new kind of empiricism', which gives primacy to sense experience and which aims at enabling students to closely observe nature and natural phenomena, is imperative. This kind of empiricism is akin to Goethe's 'delicate empiricism', which refers to empathetic and prolonged observation and which is necessary for gaining first-hand knowledge of the thing in itself, be it a natural entity, such as a flower, or a natural phenomenon, such as a flash of lightning (Hadzigeorgiou & Schulz, 2014). Of course, the development of such observation skills necessitates a restructuring and retooling of science teacher education programmes.

Approaches that have the potential to foster aesthetic experiences deserve particular attention and can be called 'aesthetic approaches'. For practical purposes, notwithstanding the obstacles and/or difficulties that need to be overcome in the context of compulsory education, there are some indicators that can help a teacher, if not to tell whether or not an experience is aesthetic and to judge the possibilities that his/her students will have an aesthetic experience through those approaches. These are:

- Curiosity and wonder about how the world works

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learning there is always intentionality—thought and consciousness are always involved and cannot be separated from the object of study. This last characteristic of phenomenological learning is not necessarily characteristic of constructivist learning; the purpose of learning, for example, is either ignored or downplayed by constructivist learning (Hadzigeorgiou, 2005b, see also van Manen, M., *Researching Lived Experience*, Albany, NY: SUNY Press, 1990). The most important questions that are associated with the constructivist perspective are (a) *ontological* (what do we know?), (b) *epistemological* (how do we know?), (c) *communicative* (how can we communicate what we know?), and (d) *technical* (what can we do with our knowledge?) (see Osborne, 1996). Without a question of purpose, however, intentionality is discouraged, as is the case with many constructivist approaches (Hadzigeorgiou, 2005b). Moreover, a question regarding how our knowledge changes the way we see science and the world, in general, is not asked by those who approach science teaching and learning from a constructivist perspective (Hadzigeorgiou & Schulz, 2014).



- Interest in science in general or in a particular area or topic
- Enthusiasm and excitement about science ideas and phenomena
- Becoming absorbed in a science activity, in and outside the classroom
- Pursuing further reading and carrying out investigations in out-of-school settings
- Change of perspective (i.e. seeing the world differently) after learning science
- Inspiration

The idea of inspiration is an important one to consider, not simply because it has both a cognitive and an emotional dimension, but also because inspiration can lead students to some kind of action. This action may refer to further reading and further thinking, an experiment that students might do at home, or even the development of a special interest in science or a particular topic. In short, it is inspiration, rather than conceptual understanding, that has the potential for taking science learning outside the school classroom. And this is why the notion of aesthetic experience—which increases the possibilities for inspiration—should be seriously considered by mainstream science education. It would be too narrow a way to define teaching effectiveness in terms of goals and objectives to be attained in the classroom, even if these goals and objectives referred to conceptual change (Hadzigeorgiou, 2002b, 2005a). Moreover, the notion of inspiration can help us reconsider what it really means to be a good teacher.<sup>9</sup>

## 2.6 Concluding Comments: The Need for Aesthetic Approaches to Teaching/Learning Science

The recent increasing attention to the notion of aesthetic/transformational experience in the context of school science teaching and learning can be justified on the grounds that such an experience shows ‘the intimate connections between learning science and interest in science’ (Wickmann, 2006, p. 145). In the context of some proposals that put an emphasis on utility and citizen science and also on sociopolitical conceptions of science (see Roth & Desautels, 2002; Roth & Lee, 2004), the idea that science learning can be an aesthetic experience is worth considering. Richard Dawkins (1998, p. 10) has been quite explicit on this:

*Far from science not being useful, my worry is that it is so useful as to overshadow and distract from its inspirational and cultural value. Usually even its sternest critics concede the usefulness of science, while completely missing the wonder.*

Elsewhere I have argued that there is a difference between students’ involvement with the events of instruction and their engagement with the scientific ideas

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<sup>9</sup>William Arthur Ward wrote: ‘the mediocre teacher tells. The good teacher explains. The superior teacher demonstrates. The great teacher inspires’ (cited in The Royal Bank Letter, 1989, p. 2). How many of those in the teaching profession would have liked to instil a zest for learning in their students? And how many would have liked to ‘inject life into inert symbols’ (Egan, 1990, p. 252)?

(Hadzigeorgiou, 1999, 2005b). Although the former could be considered a prerequisite for science learning, it is the latter we should aim at. It is for this reason that special attention should be paid to the notion of ‘inspiration’ as was previously discussed.

While it is true that an aesthetic experience, like any experience, cannot be predicted, in the sense that any experience is the unique outcome of one’s interaction with the environment, and more specifically the interaction between one’s internal conditions (i.e. prior beliefs, psychological state, interest, motivation) and the external conditions (i.e. physical and social set-up), as Dewey (1938) pointed out, curriculum developers and science teachers can increase the possibilities for students to have such an experience. The chapters that follow provide food for thought to all those interested in how to encourage and foster aesthetic experiences. Based on empirical evidence, as the respective chapters discuss, activities like storytelling, which encourage narrative thinking and ‘romantic understanding’, and also activities that refer to ‘creative science’, ‘artistic science’, and ‘wonder-full science’ have indeed the potential to encourage aesthetic experiences, through anticipation, inspiration, and deeper involvement with the object of study. This deeper involvement is crucially important since science can be ‘truly beneficial and fulfilling to the individual and society when science itself is given deeper foundation in self’ (Witz, 1996, p. 599).

The question how realistic it is for students to have an aesthetic experience in the context of compulsory education may very well translate to how realistic it is to have teachers who can implement an aesthetic pedagogy, like the one proposed by Girod et al. (2003) or by Pugh and Girod (2007) or the romantic approach to school science proposed by Hadzigeorgiou and Schulz (2014). In other words, we need teachers with passion—how many studies have indeed been conducted in order to investigate the role of teachers’ passion for knowledge and understanding in their students’ learning process? And, of course, we need teachers with a good grasp of the science content of their area. However, with an appropriate retooling of science teacher education programmes, future teachers can acquire the skills to implement and evaluate an aesthetic pedagogy.

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