MONOGRAPH

ON HUMANISTIC SCIENCE EDUCATION

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ABSTRACT

As the potency of science and its impact upon society grow, the need for a humanistic perspective on science education becomes ever more urgent. Although there is not a consensus about a humanistic conception of science education, this monograph presents a normative conception of humanistic science education, which places primacy on the notion of the involvement of the self with the object of study (i.e., a science idea, a socio-scientific issue/problem), so that both personal development and the achievement of social goals become a possibility. The monograph discusses this central notion of involvement by addressing also three other related issues/ideas, namely, the purpose of learning science, the awareness of the significance of the object of study, and the personal/aesthetic dimension of learning science, that is three notions/ideas that have not received attention by the science education community. The problems/limitations associated with these issues/ideas are also discussed. The main idea that drives the discussion throughout the monograph is that a humanistic perspective on science education should be based on a deeper involvement of the self, and therefore, the ideas of purpose, significance, and aesthetics need to be seriously considered by science educators and science teachers. On this ground, a reexamination and perhaps a reconsideration of various student-centered and socially oriented approaches are imperative.

INTRODUCTION: DELINEATING A HUMANISTIC CONCEPTION OF SCIENCE EDUCATION

Methodological sophistication cannot compensate for lack of conceptual clarity.
Egan (2005b, p. 39)

Two decades ago Newton (1986) had pointed out that "Whatever else might be the aims of education, that it should be humanistic is axiomatic" (p.475). This statement today, and in the context of science education, has acquired more meaning. For as science and technology are playing a greater and greater role in society, the need for a humanistic perspective on science education becomes more and more urgent. Given that contemporary reform efforts have implicitly or explicitly addressed the need to include the human element in both curriculum and instruction (AAAS, 1990; OECD, 2000; UNESCO, 1993, 2000) and that work in that area already exists (see Aikenhead, 2003; Hadzigeorgiou & Konsolas, 2001), a critical reflection on what it really means to humanize science education is pressing and legitimate. In a recent article in Science Education, Donnelly (2004), in acknowledging the humanistic impetus of the various reforms in science education, urged the educational community to address "more synoptically and critically" the possibilities, the methods, and the limits of humanistic science education. However, to address such an issue one has to have some idea as to what humanistic science education means. But this is a problem. There is such a multiplicity of approaches that can be considered humanistic. Aikenhead (2003), in reviewing the literature, has found that humanistic science curricula include at least one of the following elements:

- Induction, socialization or enculturation into students' local, national and global communities that are increasingly shaped by science and technology.
- The human and social dimensions of scientific practice and its consequences.
- Knowledge about science and scientists.
- Citizenship preparation for dealing with real life.
- Moral reasoning integrated with values, human concerns and scientific reasoning.
- Seeing the world through the eyes of students and significant adults.
- Playing in the culture of science as an outsider.

Evidently, this multiplicity of approaches is due to the fact that the term "human element", which is the underlying factor in the aforementioned approaches, can be interpreted as an element having both a personal and a social dimension and therefore its scope could be quite broad. Any approach that would take into account at least one of those two dimensions could be called humanistic (e.g., making the subject matter more relevant to pupils' lives, integrating moral reasoning and values with scientific reasoning, presenting science through the scientists' life stories, connecting citizenship with science learning). This problem, of course, of delimitation is an obvious one, given the lack of consensus about a humanistic conception of education in general.

In addressing, however, seriously and critically the issue of humanistic science education, some conceptual clarity is necessary, despite the vagueness and the broad scope of the term "humanistic". Given that from a humanistic perspective on education the student is not just a learner, or a "learning organism" but a human being, there are two questions to be raised: What does humanizing education, and science education in particular, mean? How can our humanistic approach to school science education do justice to students as human beings? If one takes into account the misleading ideas that have been applied in education in connection with the notions of development and learning (see Egan, 1997, 2005), and that "methodological sophistication cannot compensate for lack of conceptual clarity" (Egan, 2005, p. 39), it makes sense not just to acknowledge the problem of delimitation, but to pose the above questions and search for some conceptual clarity too.

The search for conceptual clarity leads me to consider the various approaches to education that can be considered humanistic (e.g., liberal, humanistic/therapeutic, existentialist, critical, transformative). An analysis of these approaches does show that the notion of self is central to all of them. (Hadzigeorgiou, 2005b). Although a discussion of these conceptions is beyond the scope of the paper, it is important to note the fundamental ideas upon which they are based:

- *Liberal education:* intellectual freedom, moral autonomy, creative imagination, critical thinking, initiation into the various forms of knowledge.
- *Progressive education:* self-directed learning, problem-solving, personal relevance, experience, democracy.
- *Existentialist education:* freedom of choice, authenticity, responsibility, relation between knower-known.
- *Humanistic/Therapeutic education:* self-concept, personal fulfillment, self-actualization, interpersonal relations, experiential learning.
- *Critical education:* Identity, empowerment, dialogue, problem-posing, social responsibility, social justice, critical consciousness, participatory democracy, hope, praxis.
- *Transformative education:* vision, transformation, planetary consciousness, identity, spirit, wonder, wholeness, ecological thinking, praxis.

Despite the fact these approaches do not share the same conception of the self and the ideas upon which they are based can be in conflict, a common ground on which some of these ideas can stand can be delineated. This common ground points to an education that both empowers and guides students to achieve the right tension between a sense of individuality, autonomy and authenticity and a commitment to social goals (Hadzigeorgiou, 2005b). It points to an education that does not simply place the self at the center of the educational process, but it provides opportunities for the involvement of the self, which lead to both personal development and the achievement of social goals.

From this perspective, a humanistic science education - even if one were not about to provide a definition – implies learning school science in such a way that personal development and social goals are a possibility. Such learning should result in the acquisition of scientific knowledge, the development of scientific skills and attitudes, but it should also make a contribution to students' general education. This contribution should refer to the achievement of important educational goals, such as critical and creative thinking, independent judgement, open-mindedness, cognitive perspective, moral/ethical judgment, communicative and social skills. It is in this sense that a humanistic science education should be considered as both an "education in school science" and an "education through school science". Education in school science should be a crucial component of a humanistic science curriculum given that in our attempt to humanize it (the science curriculum), we may end up downplaying or rejecting scientific knowledge for its own sake (see Roth & Lee, 2004), and even not acknowledge the contribution of scientific knowledge to personal development (see Phenix, 1982). Moreover we may downplay the contribution of scientific knowledge to enabling students to change their outlook on the world. This change of outlook has been stressed by a number of philosophers and educators, who have contended that significant learning is about that change, about the students' ability to perceive the world in an unhabitual way (see Hirst, 1972, p. 401; Jardine, Clifford & Friesen, 2003, p. 102; Schank, 2004, p. 37).

Of course, this normative conception of science education, like all normative conceptions of education, could be contested. There can be many normative conceptions education, some more contestable than others. For example, the conception of science education as/for social-political action (Roth, 2003; Roth & Desaultels, 2002) can be contested on the grounds that it is based upon an instrumentalist/pragmatist view of scientific knowledge and therefore upon a narrow conception science education itself. In viewing, as it does, science education mainly as a utilitarian project (see Roth & Lee, 2002, 2004), such a conception rejects scientific knowledge for its own sake, downplays the importance of the personal-aesthetic dimension of science, and also raises questions about intellectual curiosity, about what science content is actually learned by the students (i.e., should students learn or be encouraged to learn only content that is relevant to the community projects they engage in, or generally relevant to their immediate concerns?), and about the awareness of the larger human significance of that content. Ultimately it raises a question about whether science education is reduced to a kind of social activism (Hadzigeorgiou, 2005b).

The role of the personal/aesthetic component, and particularly the emotions experienced from doing science, should not be overlooked. Richard Feynman (1964), in taking a critical stance on the role of values in science, has stressed an all important value of science, other than utility: "the fun called intellectual enjoyment . . . which is not considered enough by those who tell us it is our social responsibility to reflect on the impact of science on society" (p. 4). Certainly scientists should reflect on the social impact of science. And certainly students should be encouraged to do the same. But this intellectual enjoyment can be part of a humanistic school science education.

There is no doubt that, from a humanistic perspective on science education, science for citizenship and for socio-political action should be important aims. However, the conception of science education as/for citizenship and socio-political action, as a reaction to its academic/scientistic tradition, might undermine or limit the possibility for students to come to appreciate science as one of the various ways to know the world; to appreciate the fact that it has something to say about some matters of significance. It is for these reasons that we need a broader conception of science education. Such a conception should do justice to science as a way to understand the world, and also as a field of inquiry that is sustained by mystery, a sense of beauty and wonder. It should also consider personal development as an important aim that complements the commitment to social goals. Such a broader conception can be more beneficial to students and society. Olson and Lang (2004) support such a conception. They believe that the important –the bigger- question in science education is about how personal development can make a contribution to citizenship education, "an educational goal that goes beyond epistemology and psychology" (p. 547).

However, I believe that attention should be paid in linking school science to what is called "citizen science" (see Jenkins, 1997, 1999, 2002), since humanistic science education should be concerned with more than just helping students use scientific knowledge in order to solve problems and make informed decisions. The issues that I raised above in connection with the conception of science education as socio-political action can also be raised here. Perhaps the strongest argument against linking science education exclusively to citizen science is the latter's focus on a knowledge-in-action approach to science learning and instrumental reason in general (see also Taylor, 1991).

Attention should also be given to the possibility of disseminating postmodern images of science and scientific inquiry, which deconstruct science (see Gross, Levitt, & Lewis, 1996; Holton, 1996). As Jenkins (1996) pointed out, science teachers may overlook science as one of the supreme achievements of the human race "as they struggle to respond to a variety of *isms*, notably multiculturalism, feminism, constructivism and postmodernism" (p. 147).

So I come again to the main point of my argument: we need a wider conception of humanistic science education; a conception that does justice to students, to society, and to science, as a field of inquiry. Evidently, this conception is a holistic one (Miller, 1990; Slattery, 1995, Slattery & Rapp, 2003; see also Capra, 1983, 2002) and, therefore, interactions among three components, that is, Self, Science and Society need to be considered. This means that the idea of the involvement of the self with the object of study (i.e., a science idea, a socio-scientific issue/problem) becomes central. For it is evident that in order for a student to be able to perceive the place of scientific knowledge in his/her life (as opposed to his/her having an understanding of the concepts and the principles of science), to think critically and creatively about issues and problems, and to be morally committed to social goals, such as social responsibility and praxis (as opposed to his/her moral understanding of certain socio-scientific issues), s/he has to be involved with her/his object of study and not simply to participate in learning in the various activities.

It should be acknowledged though that the process of the involvement of the self is a complex one. The reason is that purposes, the significance of the object of study, and an aesthetic element inherent in the process of doing science play a crucial role in that process. It is the main purpose of this monograph to shed some light on this complex process of the involvement of the self with the object of study, by discussing also the purpose of learning school science, the awareness of the significance of the object of study and also the personal/aesthetic element of science learning – ideas that need more attention than they have received in the past. Each of these ideas cannot be discussed in isolation but in relation to the others, since they are all interrelated. Nevertheless, I will try to highlight what I consider to be the important issues associated with each one of them.

THE INVOLVEMENT OF THE SELF

> *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.* Witz (1996, p. 599)

In this section I will try to answer four questions: a) What does involvement (and deeper involvement) of the self mean? b) Why is involvement of the self important from a humanist perspective on science education? c) What are the problems associated with it? and d) How can it be encouraged? There is, of course, another question concerning the wider implications of the notion of involvement for curriculum and teaching, but I choose to discuss it later in the implications section.

In answering the first question, I differentiate between "participation in a learning activity" and "involvement with the object of study". 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 magnets in a cooperative setting and enjoy it, but his/her emotions may arise out of the social context of the activity and not out of the object of study itself. In contrast, when there is involvement with the object of study emotions are not disconnected from it (object of study). Moreover, when involved, students perceive a connection between their own selves and their object of study and also the significance of that object. A female student, for example, who is helped to connect the law of universal gravitation to her own menstrual cycle, will more likely be involved with this particular object of study, in comparison with some male students who are simply interested in the physics of force and motion.

In deeper involvement, on the other hand, there is more than just a connection to the object of study. There is also an existential relationship to, and identification with, the object of study, in the sense that this object becomes part of one's identity. Although a student may perceive a connection between his/her self and the object of study, it is unlikely that this connection will always take the form of an existential relationship to that object, or that the object will become part of the student's identity. A male student, for example, who aspires to a career in football will more likely develop an existential relationship to Newton's laws of motion, as his object of study, in comparison with other students who simply play football, and who might make just a connection to that same object. It also deserves to be pointed out that identification with the object of study does not necessarily imply the development of an existential relationship to that object. Many students, for example, through personal analogies, may become “dancing molecules”, or beams of light, in order to understand their object of study. This kind of identification, although fundamental to the process of learning (as I will discuss in this section), should be distinguished from the situation in which the object of study becomes part of a student’s personal identity.

However, what also I consider important to associate with deeper involvement is the notion of “cognitive perspective”. This notion was put forward by Richard Peters (1966, 1967, 1977), and is about a kind of understanding that is related to the student’s ability to see the place of scientific knowledge "in a coherent pattern of life" (Peters 1966, 45). Seeing scientific knowledge in that pattern of everyday life does not simply mean that students perceive the relevance of scientific knowledge to their own life. It also means that students change their "general view of the world" (Peters 1967, p. 9). This change of students’ outlook cannot be considered without a change in the way students perceive themselves. It is unfortunate that the term "cognitive” may lead one to take cognitive perspective as representing a limited view of knowledge. But if cognitive perspective, as was pointed out, is about the ability of the learner to see the place of scientific 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) has pointed that out: "the notion of cognitive perspective is related to the idea of wholeness" (Scheffler 1996, 84). In this sense cognitive perspective is related to personal development and also to such notions as identity and worldview.

In the light of the aforementioned ideas, it is evident that personal development and social goals are more likely to be achieved when there is a deeper foundation in self. In this sense deeper involvement is very important, in fact central, from a humanistic perspective on science education. Of course, one might argue that deeper involvement may be considered an ideal notion – even more ideal than Dewey’s (1934) notion of aesthetic experience – and therefore a notion that is not likely to have an application in the context of compulsory education (mainly because of the nature of the latter). There is an element of truth in this argument but the point is that a humanistic science education ought to give students opportunities that encourage and facilitate deeper involvement. However, there is also an element of truth in saying that deeper involvement is encouraged when involvement is encouraged. How one can encourage involvement with the object of study I will discuss later in this section. But before I do this, I have to provide a more complete answer to the (second) question, which I raised in connection with the importance of involvement. This answer needs to include the following idea: Involvement with the object of study is central to learning in general. Why?

If all learning implies self-transcendence (see Gallagher, 1992, pp. 181-184; Phenix, 1971), then it is the relationship between the subject and the object of study that enables the former to be simultaneously both him/herself and to stand outside him/herself. As Phenix (1964, p.22) put it, “One knows something if he is at one and the same time distinct from and identified from what he knows”. Although there can be cases, in which “the separation between subject and object is overcome and a personal meeting takes place” (p. 194), knowledge of the world does presuppose a principle of duality. This duality, though, as was pointed out above, becomes possible if the subject can identify with the object of study. Therefore it (duality) should not be interpreted as a disinterested detachment, which forms the basis of what Dewey (1934, 1966) called the “spectator theory of knowledge”. It should rather be interpreted as a relationship that implies interest, even caring (see Noddings, 1992), expectations, and purposes; as a relationship that also makes possible the simultaneous change of a person’s outlook on the world and of his/her perceptions of him/herself. Such changes are supported by the view that personal identity can be constructed through learning (Liston, 2001; Godon, 2004; Greene, 2000; Sfard & Prusak, 2005; Wenger, 1998), but this needs more discussion. The reason is that the literature is not very clear about the role of the object of study itself in the process of identity-building.

According to the literature, the construction of personal identity takes place through social relationships (see Apple, 1999; Gallas, 1997), through lived experiences of practice (Wenger, 1998), and through narratives (see Sfard & Prusak, 2005). This notion of identity-building is in line with that of “education as a possibility” (see Greene, 1988; 2000; Liston, 2001). 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). 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 (see (Brickhouse, 2001; Brown, 2004; Calabrese-Barton, 1998; Calabrese-Barton & Osborne, 2001; Cleaves, 2005; Kozoll, & Osborne, 2004; Reveles, Cordova, & Kelly, 2004).

Two questions, however, should be raised: are identities only the product of significant narratives? 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, and in a more general sense, one could also ask: Are students to be viewed only as products of social interaction? The fundamental premise in Gallas’ (1997) work, for example, 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 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 both Wegner (1998) and also by Gallas (1997), Cummins (2003) and Apple (1999) is role of the actual object of study in the process of identity construction. The awareness of the significance of the object of study, as I discuss later in the relevant section, that can lead students to change their outlook on the world, also may be considered an important factor in the process of identity-building.

In considering also the notion identity-building and that of "education as a possibility", one more 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, 2004, 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? The notion of education as a possibility not only makes the posing of this question imperative, but also points to the exploration of ways to encourage involvement with science, even when a commitment to becoming a scientist has not been made. But before I do this I will discuss some problems associated with the process of the involvement of the self.

The first problem, and in connection with planning curriculum and teaching, is that the provision of activities that have the potential to lead to involvement, let alone a deeper foundation in self, is not an easy task. The reason is that, in the first place, the connection between the self and the object of study is something personal, and is therefore a matter of degree. This means that there can be more or less closer connections to the self. A female student, for example, who is helped to connect the law of universal gravitation to her own menstrual cycle, to use that same example I used before, might make a closer connection than a male student who is presumably interested in sport and is helped to understand Newton's laws through the motion of a ball. Another reason is that prior experiences may also be responsible for facilitating the connection between the self and the object of study. 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 make an easier and/or closer connection with the concepts of heat capacity and simple harmonic motion than students who did not have such prior experiences. If one were to consider the significance a student attaches to an issue or an idea, and his/her expectations and purpose regarding learning, things become more complicated.

A second problem is the possibility of a clash between worldviews. This can happen if a student's metaphysical frame is in conflict 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. 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 "scientistic" 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, 2000a), one can see how involvement with the object of study becomes problematic. Of course, there might be some engagement, a "playing of the game", but it is debatable whether such engagement leads to involvement of the self. Even though it appears that such a student has decided to cross into the culture (or sub-culture of science), it is debatable whether such crossing results in involvement.

The 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. Suppose, for example, that a student's fundamental belief in being part of Nature is in conflict with cutting seeds in half or leaves in pieces in order to observe them under a magnifying glass. What can the teacher do? It is beyond the scope of this paper to discuss in detail the issue of multiculturalism that is certainly raised in connection with notion of the involvement of the self. However, given that science – western science that is - is a component of our twentieth century worldview, it is important that science education prevents the dissemination of false images of science (Holton, 1996). In making a distinction between the epistemic universality of science and scientism, it is important that culturally diverse students come to appreciate science as a human endeavor to understand the natural world, while their own cultural knowledge is taken into account and is treated respectfully by science teachers (Southerland (2000); see also Loving, 1995; Loving & Ortiz de Montella, 2003).

A third problem that makes the process of involvement problematic is the object of study itself. This problem is not simply about students who, in engaging in an activity (e.g., a community project), do not become involved with the science content relevant to that activity, but about a compatibility between students' worldviews and certain science content (topics), or even certain disciplines. For example, some students may become involved with the study of evolution and the green house 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. Cobern's work (1996) does support this claim.

In the light of these problems a tempting question may be the following: How could involvement be encouraged? Or, in other words, are there any activities that facilitate the connection between the self and the object of study, and which (activities), therefore, have the potential to contribute and lead to a deeper involvement of the self? What has been said so far points to a number of activities that I will now discuss briefly.

Approaching science as a creative endeavor, especially through poetry (see Watts, 2001) and through the arts, is such an activity. Witz's (1996) argument that deep-based relations to the object of study occur in cases of prolonged creativity, during which "the individual subordinates him or herself to the conditions of creativity and gives him or herself to the creative impulse" (p. 599) can provide science educators with some food for thought. Immersion experiences, in general, can also be considered worthwhile activities, since they not only lead to self-directed learning but also provide opportunities for self-expression and self-actualization (see Maslow, 1971). This self-expression can be viewed in connection with the process of identity-building and is supported by Waterman (1992, 1993) who has complemented Marcia's (1988) work on identity statuses by identifying a third dimension - in addition to those of exploration and commitment - to the process of identity construction. (According to him, individuals differ not only in how open they are to exploring and to committing to identity options, but also in the passion they invest in this process.) This third dimension Waterman called "personal expressiveness" and can help us distinguish between students who look for the most practical options and those who strive to realize their inner potential. Evidently, immersion experiences can provide students with good opportunities for creative expression, and hence opportunities for exploring their "unexplored selves". Such opportunities lead to a number of identity options that students might find desirable. Pursuing personal interests in general (e.g., learning more about the physics of flight, investigating at home the freezing time of various liquids), should be included in this category of activities.

Community projects (see Roth & Lee, 2004) and storytelling (see Stinner, 1995; Hazdigeorgiou, in press) also can be considered as activities that facilitate involvement. In regard to the former, it is important that the projects give students the opportunity to imagine an improvement of their own condition (see Calabrese-Barton, 1998; Calabrese-Barton & Osborne, 2002), an opportunity for "a sense of identity, place, and hope" (Giroux, 1992, p. 170), and hence a reason for learning. In regard to the latter, it is important that students be not presented with just a series of historical events, but with a narrative, which can include, except science ideas (e.g., content knowledge and knowledge of NOS), an initial idea to incite wonder (e.g., an accidental discovery regarding the legs of a frog led to series of discoveries and inventions that changed the face of the whole world), human values (e.g., ingenuity, insistence, persistence, commitment), mental images of scientists involved in the narrative that illustrate those values, and also a moral (e.g., Galvani's discovery, despite the humiliating defeat that he suffered, was very significant since nowadays that discovery can save human lives, through the use of electrocardiography; the scientific community should not ridicule and reject scientific ideas however strange or even crazy they may seem and sound at first) (see Egan, 1997; 2005a; Hadzigeorgiou, in press). Of course, in connection with storytelling, biographies of famous scientists can also be included. Such biographies give students the opportunity for imagining possible selves, even opportunities for identifying with the some scientists (e.g., identifying with Einstein who had the same conceptual problems understanding quantum mechanics, with Marie Curie who turned down financial profit from her discovery on humanistic grounds).

In talking about storytelling, evidently, students' imaginative engagement becomes a central feature of the learning process, which brings me to the notion of "romantic understanding". This notion is important to consider since it can prove very useful in connection with the process of involving the self. According to Egan (1990), romantic understanding is a way of making sense of the world and of experience by appealing to imagination and by focusing on "the extremes of reality and its most exotic, strange and mysterious features" (p.36). Apparently, school science is a subject that can provide ample opportunities for romantic understanding (Hadzigeorgiou, 2005a). For example, science ideas can be presented, not only through storytelling, but also in a way that students sense the strangeness of these ideas (e.g., the uniform straight line motion of a spaceship at thousands miles per second but in the absence of an external force, the equivalence of rest and uniform straight line motion, the "emptiness" of solid matter, the increase of mass of a particle with the increase of its speed), or generally through mysteries, paradoxes, and the extremes of reality (e.g., the fate of the earth after the total disappearance of the sun, the mystery of universal attraction, the twins paradox in the special theory of relativity, the transmission of electromagnetic radiation through an empty and freezing space, the smallest and the biggest molecule, the fastest particle, the longest long-jump.) These ideas of mystery, paradox, and extremes of reality make us reconsider what we usually take as relevant or meaningful content in school science. And this brings me to the issue of metaphysical questions and beliefs.

Many students, who become emotionally involved with a metaphysical issue, might be discouraged from asking a question concerning such an issue (e.g., why is there such a symmetry in nature) because it is not an empirical or a "scientific" question. Teachers though should not discourage but give value to young students' metaphysical beliefs and questions. In regard to metaphysical questions, as Noddings (1993) points out, "teachers should assume that students are continually asking such questions implicitly, and, therefore that they should plan their lessons to include such material" (p. 131). Rejecting such questions, discouraging students from asking them in the first place, means discouraging involvement. On the other hand, encouraging a discussion of students' metaphysical beliefs (e.g., symmetry is a characteristic of Nature and therefore is found only on Earth but not anywhere else in the Universe) means encouraging involvement, but not just for the sake of involvement, but also for the sake of discussing the reasons behind such beliefs. Cobren (2000b), in discussing the role of knowledge and belief, and the problems arising from categorizing things as one or the other, stresses the view that "education should be much more about the reasoning than about categorizing" (p. 236).

This view can be very useful in approaching the problem of involvement in the case of students with strong religious beliefs. Given that belief in absolute (religious) truth is incompatible with (scientific) tentativeness, open-mindedness, and revision of ideas, there is indeed a serious question about whether such an incompatibility can encourage the process of the involvement of the self. However, if students come to appreciate science and religion as two different ways of experiencing the world – by appreciating the distinction between a scientific theory and an absolute religious belief, to appreciate science as one way of knowing, with a certain methodology that poses limitations to, and in fact determines, the kind of questions that one can ask during one's inquiry (see Hirst, 1974) – involvement may become a possibility. If one also considers that students' worldviews most likely include religious elements (among other cultural elements), Cobern's (1996) recommendation to give students "the opportunity to work with scientific knowledge in conjunction with other ways of knowing such as the social sciences, philosophy, aesthetics, and religion" (p. 603) should be given serious thought. For such an opportunity can encourage involvement with the object of study. Here, of course, the notion of significance comes in, which I will discus later. However, what should be pointed out is that helping students become aware of the connection between the material aspects of the natural world and their own self – since, as Phenix (1982, p. 311) had argued, "knowledge of the material world is thus at once knowledge of self and of the natural world as necessary support for personal life" – is crucial for involvement. The fact that "physical reality has both impersonal and personal aspects, and understanding these impersonal dimensions can contribute to the enrichment of personal living" (Phenix, 1982, p. 311), should provide food for thought, as far as the possibility of getting students involved with school science is concerned.

One more point though should be made here in regard to the role of practical knowledge in facilitating the process of the involvement of the self. Given that the significance of the object of study is an important factor to be considered in this process of involvement (as I will discuss later), the practicality of knowledge should be perceived from the perspective of significance rather than from that of citizen science. Although connecting school science with citizenship is a laudable goal (see Jenkins, 1997, 1999, 2002), it is important **-** if the involvement of the self is our goal **-** that practical knowledge be connected with what is useful in students' (not simply in citizen's) everyday life. Although such practical knowledge (e.g., making a flashlight from simple materials, increasing or decreasing frictional forces between surfaces, boiling water in the absence of metallic pots, keeping something cold in the summer or warm on a cold day) is part of citizen science, it is crucial that this knowledge be perceived significant by the student him/herself. I will return to this point later when I discuss the notion of significance. However, I consider it important at this point to discuss briefly the crucial role of the process of involvement from the perspective of "learning ecology".

MOTIVATION, INVOLVEMENT AND LEARNING ECOLOGY

The idea of a conceptual ecology . . . needs to be larger than the epistemological factors suggested by the history and philosophy of science.
(Strike 1992, p. 162)

The problem of motivation, of course, in connection with learning is well known (Brophy, 1987, 1999; Franken, 2001; Lepper, 1988; Raffini, 1993). Given, however, the multiplicity of factors involved in the process of motivation (e.g., prior knowledge, values regarding schooling and education, attitudes toward learning in general and science learning in particular, psychological factors, social and classroom climate, nature of tasks), the traditional constructivist approaches to school science learning, and especially the conceptual change approach, should be considered too narrow. For these approaches are based mainly on three assumptions: First, that "learning is a rational activity" and therefore we should "focus attention on what learning is, not what learning depends on" (Posner, Strike & Hewson, 1982, p. 212). Second, that "ontogenetic change in an individual's learning is analogous to the nature of change in scientific paradigms that is proposed by philosophers of science" (Pintrich, Marx & Boyle, 1993, p. 169). And third, that "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 Alsop & Watts, 1997, Cobern, 1996, Burbulis & Linn, 1991, Hadzigeorgiou & Konsolas, 2001, Limon, 2001; Solomon, 1994). In fact, Strike and Posner (1992), two of the originators of 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, emotion, motives, and goals in the process of conceptual change, point out that and "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, need to be seriously considered by science teachers and science educators, if they are to facilitate learning. They both need to consider the following three factors: a) that learning is not just a rational/cognitive activity, b) that the motives of scientists are not the same as those of students, and c) that learning science is not simply 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. Brophy (1999), in connection with the third factor, has pointed out the need for studying the value students assign to certain content knowledge, since this value is influenced by students' personal identity. There is now evidence, according to recent studies in science education, that self-identity is a crucial notion to be considered when it comes to science learning (Alsop & Watts, 1997; Brickhouse, 2001, 2003; Brown, 2004; Calabrese-Barton, 1998; Calabrese-Barton & Osborne, 2001; Cleaves, 2005; Kozoll, & Osborne, 2004; Reveles, Cordova, & Kelly, 2004).

However, what should be noted is that what is at issue here is not just the problem of considering the affective component of learning science or students' motivation, but their emotions and their motivation in connection with their object of study. For there is a distinction to be made between participation in, or the motivation to participate in, a learning activity and involvement with the object of study itself. Pugh (2004), in thinking along the same line, distinguishes between peripheral things (e.g., humor, 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 sociocientific issue of genetically modified food or the topic of magnets in a cooperative setting and enjoy them, but his/her emotions may arise out of the social context of those activities and not out of 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 students to rely on 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 is encouraged by science teachers, because their main interest is how to "sugar-coat" school science, as (Pugh, 2004, p. 194) puts it, and not how to help students "personalize" it, that is, how to connect it to their own selves. It is quite apparent that that "sugar-coating" can motivate students but it is debatable whether it leads to involvement with the object of study itself.

For example, one may very reasonably enquire whether that "sugar-coating" process can promote the development of purposes, which, as I will discuss later, are crucial for the process of involvement. It is evident that one cannot answer that question in the affirmative. Dewey (1938, p. 67) had made a distinction between "a genuine purpose" and an impulse or desire. As I had argued elsewhere (Hadzigeorgiou, 2001, p. 321),

> *The notion of motive is equivalent to that of a short-term aim that can be translated into a plan of action and is therefore narrow in scope…[A purpose] is a general commitment that gives meaning to the process of*

education, and not just to the learning process associated with the various subjects of the curriculum.

For it is quite true that a student's motives for studying mathematics or science may very well be different from his or her motives to study history or philosophy. The purpose for getting an education though is something much more general. This point leads one to think is that the principle of dualism is alive in more than one subject, and science can be one of these subjects.

Learning, of course, does presuppose a principle of duality. As Phenix (1964, p.22) put it, "One knows something if he is at one and the same time distinct from and identified from what he knows". However, this duality, as I have already pointed out, should not be interpreted as a disinterested detachment, which forms the basis of the "spectator theory of knowledge". It should rather be interpreted as a relationship with the object of study itself, which (relationship) implies interest and also caring about that object. It is this relationship that has the potential to bring the object of school science outside the school classroom and lead to transformative experiences, by making students see school science in a different way (see Girod et al., 2003; Hadzigeorgiou, 2005a; Pugh, 2004). This "different way" is not simply about students making school knowledge "less inert and more alive", but about a change of their outlook on the world, and therefore about learning. As Jardine, Clifford and Friesen (2003, p. 102) put it: "Learning, ultimately, should help students see that things can be other than as they seem, other than as they are". This is why involvement with school science – and not just the motivation to participate in learning activities -deserves attention by the science education community.

It is quite interesting to note that Witz (1996, p. 599), in arguing for reorientation of science education, in terms of morals, ethics and higher values, has pointed out that:

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. The main way in which science can become a channel for deeper personal development […] is by encouraging 'deep-based relation to (respect for, dedication to) the object of study'.

Evidently, Witz's (1996) ideas acquire more meaning in the context of current science education reform, which places primacy on the development of science literacy, and hence on the achievement of both personal and social goals (AAAS, 1990; Bybee, 1997, OECD, 2000; UNESCO, 2000). Even though the development of 'deep-based' relations to the object of study may sound unrealistic, especially in the context of compulsory education, involvement with science, as students' object of study, is not unrealistic. The ideas discussed briefly in the previous section on the process of the involvement of the self (i.e., community projects, approaching school science as a creative endeavour, storytelling) are worth considering and implementing. However, the three ideas that will be discussed in the next sections should provide the science education community with food for thought if the notion of humanistic science education is to be seriously considered.

THE PURPOSE OF LEARNING SCHOOL SCIENCE

All learning entails a commitment to human freedom, to the capacity to choose [and] the power to act to attain one's purposes. Greene (1988, p.3)

If a student cannot give a good reason answer to the question why he is studying what he is studying , he probably should not be studying it. Forshay (1970, p.34)

In this section I will try to provide answers to two questions: a) Why are purposes important in learning, and especially from a humanistic perspective? b) How can the development of purposes be encouraged in the context of school science education? In regard to the first question, it is true that there can be learning without a purpose. Imaginative engagement with school science can take place in the total absence of a purpose. Romantic understanding, according to its definition given in the previous section, does not require any purpose whatsoever. Students can be totally immersed in certain activities (e.g., listening to a story about Faraday's work in the Royal Institute) and become involved with certain content (e.g., the mysteries of time, X-rays, tsunamis) without a purpose at all. Although purposes may be developed in the course of the learning activity (e.g., a student might want to learn more about tsunamis because s/he may take a trip to an area that was hit recently by a tsunami, a student who studies volcanoes begins to negotiate an identity by imagining a career as a geologist), initial involvement can take place without a purpose. However, it needs to be pointed out that it is purpose that makes learning an intended goal rather than the accidental outcome of an activity.

Many examples can be given to support this claim: a student, may become involved with chemistry because his/her purpose is to learn about the chemistry of explosives; another student wants to learn about projectile motion and becomes involved with trajectories and parabolic paths because his/her purpose is to become more successful in scoring for his/her basketball team; another student becomes involved with the mechanics of balance and stability because his/her purpose is to become a professional gymnast; and another student simply studies anything, without becoming involved with his/her object of study, because his/her purpose is to pass the exam. In Sfard and Prusak' (2005) empirical study the students' purpose to learn mathematics emerged from their vision of a mathematics-related professional career and the expectation to become "fully-fledged" human beings.

It is quite interesting to note that Sfard and Prsak (2005), in defining identity "as collection of stories about a person or, more specifically, as those narratives about individuals that are reifying, endorsable, and significant" (p.16), distinguish between an actual and a designated identity. According to them, an actual identity consists of stories about the actual state of affairs, while a designated identity consists of stories believed to have the potential to become part of one's actual identity. They argue that "designated identities give direction to one's action and influence one's deeds to a great extent" (p. 18) and that "learning is the only hope for those who wish to close the gap between their actual and designated identities" (p. 19). Hope – an ontological need, as Freire (1998) pointed out - becomes here a central element of the learning process, an idea that had been remarked upon by Phenix (1971): "Without hope there is no learning; for the impulse to learn presupposes confidence in the possibility of improving one's existence" (p. 275). This message is of crucial importance not only in the case of marginalized students (e.g., homeless students), who more likely feel that their experiences are inferior to those of other students, but also for all students. A female student, for example, in reading about how Marie Curie completed her studies in Paris, may become more deeply involved with science (in comparison with a male student who shows an apparent interest in physics), not only because she identifies, in some ways, with Curie's life experiences, but also because she wants to excel in school science in order to counterbalance some of the elements of her identity, and generally because she hopes to improve her own condition as a human being.

Margaret Bateson's (2004) message in regard to education, namely, what is important is not what one knows but what one is willing to learn, is a case in point. If learning is about the "the capacity to surpass the given and look at things as if they could be otherwise" (Greene, 1988, p. 3), then purposes and the ability to achieve them become central to the learning process. As Greene (1988) argued, "all learning entails a commitment to human freedom, to the capacity to choose [and] the power to act to attain one's purposes" (p. 3). The question to be asked though is whether the purposes students try to attain are worthwhile. So from a humanistic perspective on education, the question "Why should we learn, or why do we want to learn, something?" becomes crucial (whether or not this is explicitly or implicitly raised, or raised at all). To this point I shall return later in this section.

In considering, of course, the involvement of the self central to learning, the question "why should I learn?" becomes more important than the questions concerning the "what to learn?" and the "how to learn?" (Hadzigeorgiou, 2001; Postman, 1995). And yet, this "why" question is extremely difficult, if not impossible, to answer. In science education this question is not even raised at all. The questions that are commonly and explicitly asked are the following (see Osborne, 1996): (a) What do we know? (the ontological question), (b) How do we know? (the procedural question), (c) What can do we with what we know? (the technological question), and (d) How can we communicate what we know? (the communicative question). An important question, namely, "Why should we know?" is missing from this list. No doubt, the above four questions are fundamental and should certainly be considered in planning curriculum and teaching, but they should neither obscure nor downplay the importance of purpose. Postman's (1995) view, that the greatest problem in education is metaphysical and not technological, should be given more serious thought by the science education community. The preoccupation with the "how" question, and hence with the development of learning theories and teaching models, shifts our attention from the heart of the problem. As Woolnough (1998, cited in Jenkins, 2000, p. 608) commented, the problem is not that these theories of learning get the answers wrong, but that they ask the wrong questions in the first place. "They seek to answer the question 'how do pupils learn?' What we ought to be asking is 'what makes students want to learn?'" This is no doubt a tough question, but it could be rephrased as follows: "What makes students want to become involved with their object of study?" Apparently the significance they attach to their object of study and the purposes the have for learning in general (and science learning in particular) and for going to school. Perhaps significance plays a greater role in the case of elementary school students (although it is difficult to develop an argument here), but purposes cannot be left out of the answer to the above question. If students are considered human beings and not just learners (or "learning organisms") then purposes are important. In the introduction, I pointed out the need for some conceptual clarification of the notion of humanistic science education. It is evident that one cannot avoid considering purposes a central element of learning, especially if the notion of "self" becomes central. These remarks bring me to the second question concerning the development of purposes in the context of school science education.

In considering that purposes are connected to expectations and hope (Hadzigeorgiou, 2001b), and that "the impulse to learn presupposes confidence in improving one's existence" (Phenix, 1971, p. 275), science educators and science teachers have a number of options as far as the development of purposes is concerned. The main point to be kept in mind is that learning activities should provide students with opportunities to imagine an improvement in their own condition. This idea of improvement is of special importance in the case of students who are marginalized for some reason or for students with disabilities (Hadzigeorgiou, 2005b). Incorporating autobiographies of famous scientists, participation in community-based projects, and approaching science as a creative endeavor are all options to consider.

In regard to the inclusion of autobiographies, students can be given the opportunity to identify with some scientists. A female student, for example, in reading about how Marie Curie completed her studies in Paris, may become more deeply involved with science (in comparison with a male student who shows an apparent interest in physics), not only because she identifies, in some ways, with Curie's life experiences, but also because she wants to excel in school science in order to counterbalance some of the elements of her identity, and generally because she hopes to improve her own condition as a human being. As a recent empirical study by Sfard and Prusak (2005) showed, excellence in mathematics was connected to students' expectation to become "fully-fledged" human beings.

In regard to participation in community-based projects, there is empirical evidence that students perceive an improvement of their own life and develop critical consciousness necessary for inquiring into the existing social conditions of their community (Calabrese-Barton, 1998; Calabrese-Barton & Osborne, 2002; Roth & Lee, 2004). Apparently, community projects, provide students with "a sense of identity, place, and hope" (Giroux, 1992, p. 170), and hence a reason for learning. This is extremely important for marginalized groups of students (e.g., homeless), who need a reason for learning, given that they feel their experiences to be inferior to those of other children.

As for the third option, science as a creative endeavor can be also considered in connection with development of purposes, since students have ample opportunities for self-expression, and hence opportunities for exploring their unexplored selves (see Waterman, 1992, 1993). Such opportunities lead to a number of identity options that students might find desirable (see Brickhouse, 2001, 2003), which, in turn, facilitate the development of purposes.

A tempting question, however, that one might ask is this: Can an explicit approach, that is, a "why-should-I-learn-school-science?" question, be helpful in developing a purpose? This approach might appear reasonable, since it is only the student him/herself who can provide an answer to that question. However, two major problems emerge here. The first is that a "why-do-we-need-to-learn-science?" kind of question can be a double-edged knife. For it may very well encourage a dualism between the subject and the object of study, and hence a separation from, and not a connection to, it. Teachers, in asking students explicitly why they should study school science, school science - the object of study - is set "out there", separate from everything else. It is therefore important that questions are not simply framed in a "why-do-we-need-to-study-science?" mode, and that students are not provided with just a list of possible reasons. (A discussion of these reasons also appears to be crucial, although this discussion cannot guarantee the development of a purpose.) On the other hand, it needs to be pointed out that the creation of a purpose is quite complex as a process, since it is related to students' aspirations, expectations, and worldview. Therefore it would be misleading to think of such a process as a linear one, in the sense that the creation of a purpose (that is, the effect) is something that is developed simply through attempting to answer the "why" kind of question (that is, the cause). In other words, it would be misleading to think that students first find a purpose by engaging in an activity and then make the decision to study science. This of course can happen, but purposes, more often than not, emerge from the development of a deep-based relation to school science or to the specific object of study, which (development of relation) requires certain experiences (i.e., participation in a community project, in an immersion activity) and this will take some time.

However, an explicit question about the purpose of learning school science can be helpful if such a question is connected to the development of an awareness of what science is, of what it can and what it cannot do. Why? Since an appreciation of science presupposes an awareness of what science is, an explicit "why-learn-science?" question can facilitate the development of this awareness. Apparently, this awareness is not developed just through an answer to such a question of purpose, but through the opportunity students have for making those explicit comparisons with other ways of knowing and experiencing the world (e.g., philosophical, aesthetic, religious). It is very crucial that students become aware that a physical phenomenon (e.g., a sunset, a rainbow) can be described by both a physicist and a poet, and that here we have two different kinds of understanding and experience. It is also crucial that they understand the difference between scientific theories and religious dogmas. It is these explicit comparisons that enable students to appreciate science as one of the various ways of knowing and experiencing the world, and which (comparisons) should come as an answer to the "why-learn-school-science?" question. Certainly these comparisons can be made in the absence of such a question. But since learning is a purposeful activity, the awareness and appreciation of what science is and what it can do (i.e., what its potential and limitations are), can be linked directly to that "why" question. It is the answer to that question that provides students with the opportunity to decide whether or not they want to become involved with science. Of course, purposes, as I have already pointed out, can emerge from certain experiences - which should be encouraged - but the importance of linking the purpose of learning school science to the appreciation of what science is should not be dismissed. Even if one argued that (abstract) scientific knowledge has no significant purpose for students (see Cobern, 1996, 2000a for empirical evidence of this), and therefore the opportunity for them to appreciate what science is cannot facilitate the development of purposes, it should be stressed that this appreciation is incomplete without students' feeling of a sense of awe and wonder, elements that define the personal/aesthetic dimension of science, which I discuss later in the paper.

It is evident that trying to find a reason, let alone a purpose, to learn about something without having even a vague idea about what that something is, can be quite absurd. The teaching, of course, of the nature of science (NOS) can help overcome this problem. Despite the complexity of the issue (of NOS) there appears to be a consensus about what ideas about science should be taught to the students (see Lederman, 1998; Osborne et al., 2003). However, the problem with learning these ideas is that they (ideas) do not say anything about why scientists are interested in doing science. Even if a justification of science in terms of the scientists' attempt to understand the world is offered, there is still a question to be answered: Why should people be interested in understanding the world? This is an important question to be raised granted that the recent science education reform agenda, explicitly or implicitly, addresses the need for understanding science: “An understanding of science and technology is central to the personal, social, professional and cultural lives of the individuals” (OECD, 2000). But this is what the policy makers are putting forward. The question is why should science, as a discipline, be central to the lives of people and particularly to the lives of students. Why should scientific knowledge be part of everybody's general knowledge? This question is very important and should be raised. But how can it be answered? By focusing on the public understanding of science and on the justification of school science in terms of various rationales (e.g., utilitarian, cultural literacy)? Although such justification is important, in the sense that it helps students become aware that science is neither a hurdle to be overcome nor a trivial pursuit, that also can be fun, it might obscure science as one particular way to understand the world. It is for this reason that explicit comparisons with other systems of thought should be made.

With students from other (non-Western) cultures questions of purpose are of crucial importance. Given that the goal of cultural transmission raises ethical issues, since students may perceive that science is forced upon them (Aikenhead, 1996), a discussion of questions of purpose can be helpful. These discussions can facilitate the building of bridges between their own culture and that of science. And in that sense they are helped to be enculturated - and not assimilated - into the world of science. Empowerment and emancipation therefore can be connected with the notion of purpose. It would be too narrow to approach emancipatory pedagogy only as problem posing or problem solving. It is argued, for example, that: "Emancipatory pedagogy is a process of teaching and learning based on problem solving rather than on transmission. It is an approach to teaching students how to think not what to think" (Swartz, 1996, p. 399). But “why to think?” is also important, and this needs to be considered. "Learning how to learn" has been a powerful slogan in science education, but it is important to recognize that "why to learn?" is also important. From the perspective of border pedagogy, it has been stressed that it is crucial that students become aware of the reasons “why they make particular ideological and affective investments in certain narratives” (Giroux, 1992, p. 176). Form the perspective of critical/emancipatory pedagogy, this view is supported also by Delpit (1988, cited in Southerland, 2000, p. 298): “culturally diverse students should be taught explicitly about “the culture of power and the codes that must be used to participate in it”. In this sense, to empower students, teachers should help them “understand the epistemological foundations of science in comparison with other systems of thought” (Southerland, 2000, p. 300).

Another way to encourage the development of purposes is by raising questions of purpose and engaging students in discussions about such questions. Most textbooks, for example, do stress the idea that scientists attempt to understand the universe, to unravel its secrets and so forth. But why should we understand the universe? It is crucial that such a question be raised and discussed. Questions of purpose also can be raised in the STS context: “Should nuclear energy be used for the production of electricity in the case of countries with no fossil fuel resources?” “Should more money be spent on the space program or for developing more effective technologies for feeding the third world?” If involvement with science is to be encouraged then school science education should go beyond NOS and technology, even beyond putting science in a human context (e.g., by using the history of science, poetry, etc.) and offer students opportunities to discuss such questions of purpose. It is these questions that raise metaphysical, ethical and value issues, and the attempt to answer them may even help the students to find reasons and even a purpose for becoming involved with school science. Of course, it might be argued that these questions do not fall in the domain of science but rather in that of philosophy. But that is the point: to provide opportunities for science to be joined with other disciplines, and hence opportunities for students to come to appreciate science as one way of knowing, as a field of inquiry that can answer certain questions, as one way of knowing and experiencing the world, not better than, or superior to, other ways but just different. From the perspective of worldview theory such opportunities have the potential to encourage involvement (see Cobern, 1996).

In connection with questions of purpose, however, the aims of science itself also deserve particular attention. Engaging in fact students in discussions about the aims of science, as an academic field of study, should be considered an activity that may encourage the development of purposes. In discussing the aims of science (as an academic discipline) students, especially those in the upper grades of high school, are given the opportunity not just to become aware of why they are participating in an activity, but also to become aware of the significance of their activity in the wider context of humanity, which (significance), in turn, can facilitate the development of purposes. Although I will discuss the notion of significance in the next section, here a question should be raised: Are students aware of the significance of their activities in the wider context of humanity?

It might be argued, for example, that even activities in the Science-Technology-Society (STS) context, which represent a humanistic approach to school science education, cannot provide the opportunity for a meaningful experience if students do not become aware of the potential role of that activity in improving the human condition. Although the awareness of the possibility of improving one's own condition is crucial, the awareness of that possibility in a larger framework is also important. Otherwise, STS activities might be received as ordinary experiences that do not differ very much from other activities, and be considered as an effort on the part of the science education community to assimilate all students into the culture of science.

It could also be argued that the STS approach would be considered more effective in the context of science education if the scientific community devoted itself to the interests of humanity. The argument here is not that academic scientific inquiry does not have humanistic goals, but that a social reconstructionist approach to school science education would be more effective if scientists devoted themselves to studying the same or similar issues and problems (see Maxwell 1992). Although it is not my purpose to raise an argument about how scientific research should be conducted, a question about the message students receive from the mass media and the society in general concerning the purpose of science (as a field of academic inquiry) is certainly raised. It is therefore for this reason that the aims of science and the issues raised by them be discussed. School science education, in that sense, can also pave the way for the improvement of the aims of science.

> *In order to be rational, we must be ready to look critically and imaginatively at our aims, to give ourselves the opportunity to discover how to pursue more desirable or more realizable aims; we must be ready to ask why we are pursuing the aims we are pursuing - in both the rationalistic, and historical or causal senses of "why" - so that we may discover ways in which our aims can be improved.* (Maxwell, 1984, p. 93)

The discussion, of course, about the aims of science raises an important question about why students study science in school. It is quite reasonable to say that students study school science for a number of reasons (e.g., because their parents say so, because they have to, because it is interesting, fun, etc). For the sake of the argument, let us say that a student wants to study school science because it is, or can be, fun. Learning school science as a fun activity is important, since it can lead to the search for knowledge for its own sake, a humanistic goal that should be encouraged (see Maxwell, 1984, 1992). A student, for example, who becomes involved with projectile motion and enjoys calculating the paths described by the bomb, the distances traveled by it, the time it takes to reach a target, etc, engages in a worthwhile activity. But the question is: does this student become aware of the wider implications of what s/he is studying? Another student, to take another example, may become involved with chemistry because his/her purpose is to learn the chemistry of explosives. Although this purpose, in and by itself, presents no problem at all, the point to be raised is why should that student want to learn that thing. Has the student developed an awareness of the wider implications of his/her object of study? The point I am trying to make is that, from a humanist perspective on school science education, these wider implications are crucial for students to understand since they are helped to develop humanistic purposes. Whether a male student wants to study projectile motion because he simply enjoys it, or whether a female student wants to learn about projectile motion because her purpose is to become more successful in scoring for his/her team while playing basketball, the wider implications and larger significance of “projectile motion” are to be considered. I am using these examples on purpose because they “appear” to involve no values, no ethical judgements and wider implications, when compared with examples illustrating socio-scientific issues or even certain concepts, like energy. But it is important to note that all ideas, all issues, have both a personal and a wider human significance. For as Pekarsky (1982, p. 351) put it, “if the ‘little scientists’ of the classroom were encouraged to reflect on the larger human significance of what they were studying, the adult scientists of the future would be more likely to do the same”. The issue of significance, of course, I will discuss in the next section of this essay. But I made a reference to it because it leads me to the issue of developing humanistic purposes: A humanistic science education <u>ought</u> to develop in students, not simply worthwhile, but also humanistic purposes. These humanistic purposes may even turn into a purpose for learning school science, something that also can lead to a deeper involvement of the self.

But more to the point of developing humanistic purposes in the context of school science education. Suppose that students become involved in a number of community projects. They learn certain content that is most likely relevant to their projects, they develop science process skills and also social skills. But should those students not learn about tsunamis, for example, about what they are, what their wider consequences might be, etc., on the grounds that tsunamis are not part of students’ local environment, or not one their immediate concerns? These questions bring me back to the question concerning the reasons for studying certain ideas, topics, problems, etc., and the aims of science as an academic field of study. Knowledge about tsunamis, to use the above example, is important, and this can be connected to a discussion about the aims of science, as a field of academic inquiry. Such discussion, as I have already pointed out, can help provide some students with a purpose for learning school science. It is crucial that, through this discussion, students become aware that scientific inquiry relates directly to the improvement of human life, even to the survival of humankind.

So, I conclude, the question "why learn school science?" remains a central one, from a humanistic perspective on science education. Although students themselves may never ask explicitly that question, what they choose to learn (and what to be ignorant about) is tied to certain purposes, which emerge from the significance they attach to their object of study. In this sense, the “why-learn-school-science?” question is asked implicitly by the students. On the other hand, an awareness of what science is, what it can and what it cannot do, and also what it can help students do, are all crucially important for developing a purpose. This awareness though can also be linked directly to the purpose of learning science through an explicit “why-learn-school -science?” question. Even if objections are raised against this argument, there remains another question: If students’ ideas about natural phenomena should be made explicit, if students should be taught explicitly about certain ideas about science, then why should not students be given the opportunity to discuss, to make explicit their ideas about the aims of science, as an academic field, and about their own purpose of learning school science? It needs to be recognized that purposes can be developed through questions of purpose. The difficulty to provide some answers to such questions of purpose does not entail that attempts to raise them in a number of various contexts should not be made.

THE AWARENESS OF THE SIGNIFICANCE OF THE OBJECT OF STUDY

> *Knowledge of the world in its material aspects is an important dimension of knowledge of personal being and the environing world that is the necessary context for personal existence. Knowledge of the material world is thus at once knowledge of self and of the natural world as necessary support for personal life.* (Phenix, 1982, p. 311)

> *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 (2004, p. 590)

No doubt significance is an important notion to consider in the context of humanistic education. The discussion in the previous sections points to the relationship between involvement, purpose and significance: students will more likely be involved with the object of study, if that object has some personal significance. Purposes also can arise out of the awareness of the significance of the object of study. In this section I will try to provide an answer to the following question: Why is awareness of the significance of the object of study crucial from a humanistic perspective on science education? In doing so I consider not only the significance of the content of school science but also the significance of social problems and issues that students might investigate. I will first address that issue of the significance of scientific ideas, given that the content of science, if not under an attack by the socially oriented approaches (see Jenkins, 2002; Roth & Lee, 2002, 2004), appears to be placed in the background of the curriculum.

Starting from the fact that involvement with scientific knowledge is a problematic issue (as has already been discussed in the first section), the contextualization of scientific knowledge is a reasonable option to be considered in connection with the involvement of the self. Of course, the argument against decontextualized scientific understanding is a valid one: scientific knowledge cannot be applied directly to everyday life; if transference of this knowledge is a goal, then contextualization of scientific knowledge becomes imperative (see Jenkins, 1997, 2002). But the question to be asked is whether such a contextualization facilitates the involvement of the self (-a point that I have already raised). Although topics and problems concerning technology, “kitchen science”, sports science, even a kind of "grandma science" help students connect school science with the everyday world, although an investigation of such topics and problems helps provide opportunities for students to approach science as inquiry and therefore develop inquiry skills and even practical reason, the question is whether they become aware that their own life is ultimately connected with science. In this sense, what is really at issue is not just the contextualization of scientific knowledge but its presentation so that the involvement of self is encouraged and sustained. And this is where significance comes in. Students will decide to become involved with scientific knowledge if they become aware of the personal significance of it. What do the scientific facts and principles mean to them personally? By addressing such a question the context is not to be found simply in the everyday world but in the student him/herself. It is one thing to use Ohm's law, for example, to understand technological applications, to solve problems involving batteries and resistors, and another thing to be aware that the resistance of one's own skin will determine in certain circumstances one's chances to be alive. In this sense it is not just a connection between science and everyday life, or even students' own life, but the emotional significance certain ideas have for the student him/herself (Hadzigeorgiou, 2005a).

The crucial question, therefore, is whether students become aware of the significance of science ideas. Certainly they are encouraged to “understand” scientific ideas. They are encouraged to understand the Second Law of Thermodynamics, to use Snow's (1969) famous example. They are not encouraged to memorize it and to recite it. Even students would agree that memorizing that law does not appear to have more value than knowing the length of the Nile or the height of the Alps. But are students aware of the personal and also the wider significance of that law? To take another example, several students, whether or not they have memorized the chemical reaction of photosynthesis, are able to make concepts maps, in which they connect the relevant concepts and ideas. But the question is: Do students perceive in those connections their own self (Hadzigeorgiou, 1997)? Do students perceive in those connections the wider world? Do they grasp the larger significance of photosynthesis? Many students appreciate the various technological applications as part of their daily life, and, in fact, through these applications, they can understand science. But are students aware that the various technological applications are fundamental to human welfare, and to their being human? Are they aware, for example, that life without a water system and electricity is indeed a primitive life? These questions point not only to the fact that science is intricately linked to our own self, but also to an educational imperative: it is the significance of ideas and not just the understanding of concepts that is crucial from a humanistic perspective on science education.

The awareness of significance of scientific ideas is, of course, a complex process and it is related to a number of factors. Prior experience, for example, is one such factor, for it might facilitate a closer connection between the self and the object of study, if the latter has a greater emotional significance for the student. Using the same examples that I used previously, it can be said that for a student, who has had a prior experience with an earthquake, the study of simple harmonic motion may be of greater emotional significance in comparison with a student who studies the concept of heat capacity and connects that concept to a prior experience concerning a piece of pizza that burned his/her mouth. Another factor might the difference between the practical and the emotional significance of an idea. This difference, in fact, can show that contextualization, although important for the transference of scientific knowledge, is no guarantee for the involvement of the self. For example, a student may become involved with quantum mechanics not because its ideas (e.g., the principles of complementarity and uncertainty) have any immediate practical applications in his/her life, but because such ideas help students change the way they see things. Even if an argument were raised about the practical significance of such quantum mechanics ideas - Planck's formula E=hv, for example, does have an immense practical significance, since life on the planet becomes possible due to the transmission of energy in discreet amounts – the "immediate" practical significance of such ideas does not become apparent in comparison with the various technological and other practical applications of scientific knowledge. The idea that solid matter consists of empty space, to take another example, although of no immediate practical significance, may make students change their outlook on everyday things. My own empirical observations and also Pugh's (2004) empirical study, which reports on a kind of "transformative" understanding that helps students see everyday events involving force and motion differently, support my claim. So my point is that involvement may be encouraged if students become aware not just of the immediate practical significance of an idea (e.g., the application of the principle of stability in performing successfully floor activities in gymnastics, the various technological applications of electromagnetic induction), but of its emotional significance too. (Certainly the emotional significance of some ideas does not become easily apparent or apparent at all. The idea that magnetic fields exert forces on moving charges, to take an extreme example, most likely is not perceived as emotionally significant by students - although its practical significance may become more easily apparent - when compared with the theory of evolution, to take another extreme example. But this is an issue that I have already raised in the first section of the paper in connection with the problems associated with the involvement of the self.)

From a humanistic perspective on school science education the importance of the awareness of the emotional significance of an idea is quite crucial, since it 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, Pugh, and The Deweyan Ideas Group at Michigan State University (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)

Previously I used as an example a student who aspires to become a football-player and who develops an existential relationship to the object of study (i.e., forces and motion), because football is or is becoming part of that students' identity. Although one might question whether that particular student will become involved with science, as his/her general or larger object of study, it is nevertheless important to stress that his/her involvement with a certain object of study (i.e., forces and motion) - which has an emotional significance for him/her-, is related to his/her own identity and to a certain purpose that he or she strives to achieve. To paraphrase Alsop and Watts (1997, p. 648), that student's involvement with the object of study fits his/her self-image and lifestyle.

What needs to be pointed out here is that if "Science for All" is a vision and not just a slogan, it should provide guidance for science education for all students. Therefore, the achievement of an important goal, that is, attracting the next generation of scientists, science educators and science teachers, should not be overlooked. The achievement of another goal, that is, helping students from marginalized groups to expand their cognitive horizons, should not be overlooked either. Bringing those "outsiders" of school science in is certainly very important (see Brickhouse, 1994, 2001, 2003). Although those marginalized students' lived experiences are crucial for the development of critical consciousness (see Calabrese-Barton, 1998), going beyond these experiences is also crucial. It is likely that, in the name of liberating those students (i.e, by helping them develop critical consciousness), we condemn them to stay comfortably (or uncomfortably) within their current frame of thinking or stereotype. Giving therefore all students the opportunity to become aware of the significance of science ideas means giving them identity options.

However, the significance of the various social issues and problems that students study is also of crucial importance, and this needs to be considered. Why? In talking about the aim of developing informed citizenry, that is, citizens who can make decisions about issues which have a scientific dimension (see Bybee, 1997; Cross, 1999; Hodson, 2003; Jenkins, 1997; 1999; Osborne, 2000; UNESCO, 2000), a question regarding the degree of the involvement of the self in such issues, is certainly raised. For it should be kept in mind that mere participation in project work on a social issue or problem is no guarantee for the development of an awareness of the significance of the issue or problem (Hadzigeorgiou, 1997). In considering also a problem that Dewey (1966) had pointed out, namely, "the problem of an individual consciousness acting on behalf of social interests" (p.314), the issue of the involvement of the self with social issues and problems becomes problematic. Even if commitment to social goals is a possibility, it could be argued that social responsibility and praxis presuppose an awareness of the significance of social issues and problems. In this sense, it is not just (or only) the commitment to social goals but also the awareness and understanding of social issues and problems which represent a real challenge for education and science education in particular.

Are there ways to help students become aware of the significance of social issues and problems? Participation in community projects (Roth & Lee, 2002, 2004) can be a starting point. By starting from their immediate environment students are helped to develop an awareness of being part of an issue/problem. But it is imperative that they also engage in serious discussions about such issues and problems, so that they develop an awareness of their significance. This significance, in turn, can lead to a deeper involvement of the self. But here an important question should be raised: should students study only these local issues because these issues facilitate what Michel Polanyi (1959, p.66) called “indwelling and association”? Although it may be true that students associate and even identify with their local issues and problems, since these issues problems have some personal significance, there is a question concerning students’ involvement with problems and issues that transcend their own locality. And, apart from this question, should not students be helped to become aware of the larger significance of their local issues and problems? So from a humanistic perspective the development of the "big picture", of a global awareness, is crucially important since it can facilitate the awareness of both being part of a larger problem and its wider significance.

Having already argued that prior experience can be a factor to be considered in the process of the involvement of the self with the object of study, it would not be an exaggeration to say that an STS curriculum focused upon world problems would be more appropriate for third than first world students, since it is the former who are more likely to experience an association with such problems. It is for this reason that the development of global awareness should be an educational goal. And it is for this reason that over the past decade notions such as "cosmic and interrelational consciousness" (Doll, 1993, p. 181), "interdependence, and global responsibility" (Postman, 1995, p. 112), and expansion of the "horizon of consciousness to the universe itself" (O'Sullivan, 2002, p. 7) have been seriously stressed. It is evident that these ideas point not simply to an articulation of a planetary context for education, but an expansion of the notion of critical thinking and critical consciousness to a planetary consciousness. This planetary consciousness is an important notion to consider, especially if science education is to make, in some way, a contribution to the betterment of human life. It is an important notion because also it can help with the fundamental problem of meaning in education. Oliver and Gershman (1989), in making a distinction between "technical" and "ontological" knowing, pointed out the importance of the latter in the process of meaning construction. Its central quality, as they argued, is "one's feeling for tentative connection . . . to the larger world" (p. 14).

But how can planetary consciousness be developed in the context school science education? This question brings me to a number of strategies/activities concerning the development of an awareness of the significance of various issues and problems – even those that transcend students' immediate environment. These strategies/activities necessitate, if not a total reorientation of science education, the reconsideration of what we normally consider "standard" science education ideas and activities. For example, the development of planetary consciousness can begin with the development of a critical awareness that we all share and live on the same planet. "Shared narratives" is an important idea to consider here. If, as Postman (1995) argues, "the idea of public education depends on the existence of shared narratives" (p.16), then the problems encountered in the teaching and learning of science should not be sought only in the context of science education, not only in epistemology, but also in the alienation from schooling in general and from science in particular due to the lack of shared narratives. Postman recommends that our "spaceship-earth" can be such a shared narrative. In this case the whole universe is to be understood as story. According to O'Sullivan (2002), this story of the universe is an important one to think about. He points out that:

> *The difficulty is that scientists have until recently given us the story only in its physical aspects not in the full depth of its reality or in the full richness of its meaning. The greatest single need for survival of the earth or of the human community in the late twentieth century is for an integral telling of the Great Story of the Universe.* (O'Sullivan, 2002, p. 7)

Apparently this "Great Story" can and should be incorporated into interdisciplinary units.

In connection with the narrative of our "spaceship-earth" - a useful and promising idea, especially in the context of early childhood science education - the idea to encourage holistic thinking should also be considered. This means students are helped to become aware of the interconnection of human issues, problems, and their own life. This interconnection, in turn, can facilitate the awareness that the apparent insignificance of some global issues and problems can be very significant indeed. It should be noted that Gregory Bateson (1979) had recommended that the idea of interrelationship be introduced to all grades of education. Participation in projects on global problems that necessitate the collaboration of schools from a number of different parts of the globe can be considered an activity that has the potential to promote holistic thinking (see Hadzigeorgiou, 1997; Hadzigeorgiou & Konsolas, 2001; Hassard & Weisberg, 1999). However, at the heart of the idea of planetary consciousness is the development of a proper relationship between self and Nature. This relationship deserves some space for discussion.

Evidently, the ideas of interconnection and interrelationship make the development of a proper relationship between self and the natural world a primary concern for education (see Bonnett, 2000, 2004; Slattery, 1995; Slattery & Rapp, 2003). If Bonnett (2000, 2004) is right in arguing that the relationship between self and Nature defines both our existence and our relationship with the world at large, then a change in our relationship with Nature results in a change of our outlook, our worldview, and hence in a reconsideration of our own identity. Given the problems and the state of the planet, education has the responsibility to promote this change by encouraging a respect for natural world, by helping students understand themselves as part of it (see Capra, 1983; 2002; Slattery & Rapp, 2003). In the context of science education such a change in worldview could be promoted if students became aware of the significance of certain ideas (e.g., plants are the only organisms on the planet that transform solar energy into food, and hence our own survival is ultimately dependent upon the natural world), and also if the natural world were made students' larger object of study. (The implications of this idea I discuss briefly in the conclusions.)

But there are problems. On the one hand, the empirical treatment of Nature – a fundamental element of the scientific worldview – conflicts with the idea of respect for Nature (as I have already discussed in the first section). It also conflicts with the idea of the self as part of Nature. In fact, one might argue, the empirical treatment of the natural world perpetuates the dichotomy between self and Nature. A preoccupation with modeling activities may also contribute to this dichotomy. Students, like scientists, may become enamored of their models and their possibilities (by manipulating these models), and thus forget about their actual object of study, that is, the natural world (see Witz, 1996). So the development of an existential relationship to Nature is discouraged. On the other hand, encouraging respect for the natural world, helping students understand that the view of nature as separate from ourselves is a false dichotomy, may be a moral imperative, but is it a universal one? In considering the problems concerning the involvement of the self (that I discussed in the first section) as well as the moral/ethical issues involved in the process of changing students' worldviews, and more specifically their metaphysical views about Nature, promoting such a change becomes problematic. This is true not only in the case of students from non-Western cultures, but also with students from the Western culture. Of course, with culturally diverse students this issue becomes more complicated. So the point is to help students develop an awareness of the significance of the problems associated with the state of the planet. In the case of culturally diverse students, this significance should be from their perspective. Helping them to appreciate the role that western science, through its applications, played in the degradation of Nature, helping them appreciate the fact they too share the same planet and are affected by the same problems, may be a way to facilitate respect for the natural world and hence the development of planetary consciousness. That idea that the moral imperative for respect for Nature - and the appreciation that human beings are part of it - is a universal one, needs to be appreciated from students' own perspective. This appreciation is not enculturation and therefore no guarantee for a change of their worldviews. Nevertheless it is an idea worth considering if the development of planetary consciousness and the construction of their identity as a planetary species is given serious thought.

The general point that needs to made here is that a change in worldview, from a mechanistic to a holistic-ecological one (Slattery, 1995; Slattery & Rapp, 2003), is not something that takes place through mere participation in a number of STS activities, and this represents a challenge for the science education community. I believe that the personal significance of the object of study and its larger human significance play a crucial, if not primary, role in transforming a person's outlook on the world. Although the question "what is significant for a student?" cannot –and should not – be answered in the context of science education alone, it is important to stress that significance is associated with personal identity and purpose, ideas that I have already discussed in connection with the process of the involvement of the self. However, significance should also be linked to such notions as beauty, mystery, awe, and wonder. In considering the role that worldview plays in the process of involvement, these notions are very important, since they can be part of students' metaphysical framework – a framework that provides and sustains meaning in their life. This brings me to the personal/aesthetic dimension of doing and learning science.

THE AESTHETIC ELEMENT OF SCHOOL SCIENCE LEARNING

> *Scientific experience is laden with aesthetic content of the beautiful, which is manifest both in the particulars of presenting and experiencing the phenomenon under investigation, and the broader theoretical formulation that binds the facts into unitary wholes.* Tauber (1996, p. 1)

Having considered the issue of the involvement of the self central to humanistic science education, the role of the aesthetic element of school science in that process of involvement is not as evident as the role of purpose and/or significance. Of course, this aesthetic element can be linked directly to the notion of beauty (e.g., a beautiful experiment, a beautiful image provided by a microscope), in which case its role in motivating some students has to be acknowledged. But even though this motivation is no guarantee for involvement, there is a problem concerning the appreciation of beauty in the first place. In acknowledging the differences between scientists and students (e.g., different purposes, different motives, different conceptual frameworks), the important question is whether students are capable of appreciating beauty while engaged in school science. In saying this, however, another problem emerges, namely, the subjective nature of beauty. For example, one might raise the following question: What is a beautiful experiment, a beautiful image, a beautiful formula? For a third grader beauty may lie in the colors of a physical phenomenon or experiment, while for a scientist beauty may be found in simplicity, in symmetry, or even in complexity. For Michael Faraday (1978) beauty was something else. In his *The Chemical History of a Candle* he says that the beauty of the candle is not the prettiness of its colors or its shape but the fact that it taps all the known laws of the universe: not the best-looking, but the best-acting thing. Richard Feynman made a similar point: beauty lies in the various interconnections of natural phenomena and science ideas.

> *The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree. [A]nd in the ash is the small remnant of the part which did not come from air, that came from the solid earth, instead. These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others.* (Feynman, cited in Girod, Ran, & Schepige, 2003, p. 575).

The history of science, however, provides many examples of scientists whose thinking was rooted in an aesthetic appreciation of visual symmetry (see McAllister, 1996).

Perhaps the most striking example is that of Paul Dirac (1963), who made the well-known statement "It is more important to have beauty in one's equations than to have them fit the experiment" (Dirac, 1963, p.47). It should be noted here that the Pythagorean-Platonic linkage between mathematical abstraction and beauty, and generally between epistemology and aesthetics, was revived and became important in the twentieth century with the advent of quantum mechanics. Both Bohr and Heisenberg, by using the idea of art and science as parallel symbolic systems, aligned the study of aesthetics with abstraction in science (see Chevalley, 1996). The search, of course, for some parallels between science and art, even a search for shared philosophical foundations, is challenging and promising (see Tauber, 1996).

However, the crucial question is this: Is beauty to be linked solely to mathematical concepts? In reducing the aesthetic element of science to a visual consumption of objects and/or to mathematical abstraction an important fact is overlooked: scientific inquiry is a creative endeavor, in which, emotions, aesthetics, imagination and cognition form an integrated whole. For this reason, the aesthetic element should also be sought in that personal experience of doing science, and hence linked to such notions as mystery, awe, wonder, imagination, inspiration. It is interesting to note that many renowned scientists (including Einstein himself) have made an explicit reference to these notions as crucial factors that drove and sustained their work (see Root-Bernstein, 1996, 2002; see also Midgley, 2000, p.186-187; Thomas, 1983, pp. 150-157; Wilson, 1986, p. 10, for the role of mystery and wonder in scientific inquiry).

It is true, of course, that the aesthetic element of scientific inquiry does not become evident like other elements (e.g., intellectual, ethical). Yet that element does emerge when scientists speak autobiographically about their work and the work of other scientists (see McAllister, 1996; Root-Bernstein, 1996). This confusion between what scientists do and what they actually report is pointed out by Root-Bernstein (2002): at the heart of many of the unsolved problem concerning scientific thinking is a confusion "of the form and content of the final translations with the hidden means by which scientific insights are actually achieved" (p.61). It also true that the aesthetic element is ignored by research on the nature of science, although the idea that doing science involves a creative element is acknowledged (see Osborne et al., 2003).

I do not think I need to devote space for discussing the difference between the academic scientific inquiry and school science education. But what is important to stress is that if knowledge about science (i.e., about NOS) is considered important for students to appreciate science as a way of knowing and experiencing the natural world, then the personal/aesthetic element of doing and experiencing science should also be reflected in school science education. In this context (of school science education) the personal/ aesthetic element can be linked to Dewey's (1934) notion of "aesthetic experience" (see also Wong et al. 2001), to Egan's notion of "romantic understanding" (see also Hadzigeorgiou, 2005a), to Root-Bernstein's (2002) notion of "aesthetic cognition" (see also Girod et al. 2003), to Pugh's (2004) notion of "transformative experience", and also to Taylor's (1998) notion of "poetic experience". What is common among all these notions is they all acknowledge the need for a wider view of knowledge, which goes beyond cognitive factors, beyond practical knowledge that leads to problem solving, and for the need for more holistic experiences.

The discussion in the first section of the paper about the process of involvement of the self provides a justification of the crucial importance of the personal/aesthetic element of science. The notions of wonder and inspiration though deserve particular attention. Why? As a philosophical exploration of wonder reveals, wonder inspires one's interests, it gives things their infinite significance, it invites one's reflection upon the notions of self and life in general, and it can even reach to very heart of one's identity (Hove, 1996; Verhoven, 1972). In this sense, wonder plays a crucial role in the development of a "deep-based" relation to and respect for science, and therefore a role in one's worldview. Witz (1996) argues that this respect can be considered a preliminary "to higher aesthetic and transcendental inner knowing" (p. 599), and recommends that wonder be given the highest place in science education, and be regarded "a feature and a goal of science education itself" (p. 603). These ideas, no doubt, point to the importance of activities that evoke wonder and hence their inclusion in the curriculum.

However, what is important to note, is that, in line with worldview theory (see Cobern, 1996), wonder can be also considered in connection with the process of conceptual change. In defining, of course, wonder as "the emotion caused by the perception of something novel and unexpected or inexplicable", as "astonishment mingled with perplexity or bewildered curiosity" and as "the state of mind in which this emotion exists" (Hove, 1996, p.442), one simply asserts its value in the learning process. But in approaching it as a state of mind that signals the limits of a student's present understanding, wonder can lead to inquiries, not simply within an accepted framework, but into the framework itself (Opdal, 2001). In this sense, one asserts the importance of wonder in the process of conceptual change (Hadzigeorgiou, 2005a)

However, two problems in regard to wonder need to be acknowledged. The first one is about the passivity inherent in wonder. For although it is true that wonder can give things their significance (see Hove, 1996; Verhoven, 1972), a passive contemplation of natural phenomena may discourage curiosity and the drive for scientific inquiry. As Taylor (1998, p. 169) argued,

> *Curiosity belongs to the scientific impulse and would strive to dominate nature; whereas, wonder is poetic and is content to view things in their wholeness and full context […] When a flower is taken apart and examined*

> *as pistil, stamen, stem and petals, each part is seen exactly and a certain curiosity is satisfied; however, curiosity is not wonder, the former being the itch to take apart, the latter to gaze on things as they are.*

Given that school science education cannot avoid encouraging curiosity and the drive to analyze, in order for students to study the natural world, the problem of developing in students the right a tension between curiosity and a sense of wonder is quite apparent.

The second problem concerns the involvement of the self with object of study: Does the inspiration derived from a sense of wonder facilitate involvement of the self? As I have already discussed in the first section of the paper (in regard to the problems associated with the process of involvement), there can be a mismatch between a student's worldview and the scientific worldview, in which case, wonder becomes an obstacle to involvement with the object of study, and therefore an obstacle to scientific understanding. Wonder, for example may derive from a student's sense of the beauty of natural world, which (beauty) may be absent either from the object of study itself (e.g., electromagnetic induction, optical refraction) or from the way this object is presented to the students (e.g., presenting electromagnetic induction through a demonstration experiment complimented with an exposition of basic ideas and followed by hands-on activities). This absence, apparently, is an obstacle to that student's involvement with the object of study.

But wonder can also be evoked if students are given the opportunity to understand their object of study romantically by employing their imagination. Elsewhere I have explored the potential role of Kieran Egan's (1990) notion of romantic understanding for science education (Hadzigeorgiou, 2005a). But, as I have already pointed out in the first section, even "abstract ideas" can be understood "romantically" by students (by helping them feel a sense of mystery and wonder, which is inherent in natural phenomena and science ideas), and, in this sense, romantic understanding becomes a prerequisite for what we have called conceptual understanding. Romantic understanding, in giving students the opportunity to view the world differently, is transformative. The empirical studies by Girod et al. (2003) and by Pugh (2004) report on such an aesthetic/transformative kind of understanding: students come to understand everyday phenomena involving force and motion differently. This different view can incite wonder, it can inspire interests, it can lead to the development of cognitive perspective (see first section of the paper), and therefore to a deeper involvement of the self. The above studies provide evidence that even abstract knowledge can inspire students if presented appropriately (see also Hadzigeorgiou, 2005a). They also provide evidence that it is the way the object of study is presented to the students that makes the difference between their involvement with that object and their mere participation in the events of instruction (Hadzigeorgiou, 1999). In acknowledging this difference, one acknowledges the crucial role of the aesthetic element of school science learning. It is unfortunate that this aesthetic element is not considered by recent reform efforts (see OECD, 2000; UNESCO, 2000), which promote a utilitarian view of scientific knowledge.

In concluding this section I should point out that the notions of wonder and inspiration are closely linked to the personal/aesthetic element of science and to that of “transformation”. This last notion of “transformation” is what we should keep in mind, since it is students’ transformation of outlook that makes them perceive school science and natural phenomena in a different or “unhabitual” way. This view, of course, has been stressed by a number of educators and philosophers, who have argued that significant learning is directly related to a change of students’ outlook, to their ability to perceive the world in an different way (see Hirst, 1972, p. 401; Jardine, Clifford &Friesen, 2003, p. 102; Peters, 1967, p. 9; Schank, 2004, p. 37). And as Richard Peters pointed out, "To be educated is not to have arrived at a destination; it is to travel with a different view" (Peters, 1973, p. 20).

IMPLICATIONS FOR CURRICULUM AND INSTRUCTION

> *Learning science is not only a matter of acquiring knowledge but it is also a matter of deciding what kind of person you are and want to be.* Brickhouse (2003, p.93)

> *Science education should encourage a deep-based relation to (respect for, dedication to) the object of study as part of a larger orientation to life, the world and existence.* Witz (1996, p. 597)

Undoubtedly, the ideas of involvement, purpose, significance and aesthetics raise a number of important issues for school science education. The problems inherent in these ideas –several of which I have discussed – raise more issues and questions that invite philosophical contemplation. Although it is beyond the scope of this monograph to pursue all these ideas and issues further, a brief discussion of some broad practical implications of the central notion of involvement for curriculum and teaching is imperative.

The first important implication is to reconsider the well-known "start-from-the –learner" idea. The idea, of course, to start from the learner is no doubt fundamental. For more than three decades the well-known Ausubelian view, that the single most important factor influencing learning is what the learner already knows, has been guiding science educators and teachers, especially those who espoused a constructivist epistemology. However, if the notion of the self is seriously considered, starting from the learner should be interpreted as taking into account his/her fears, anxieties, expectations and perceptions of him/herself, his/her metaphysical beliefs, his/her beliefs about education and learning in general and science learning in particular. In this sense, the idea that the single most important factor in the learning process is "what the learner already knows" needs to be reconsidered. In helping students to learn science, science educators need to think about more than just the "learner's prior ideas". Students' cultural background, their personal identity and worldview are all crucial factors in the process of involvement. In considering the notion of identity in particular, the learner's perception of him/herself, becomes of crucial importance. From the perspective that I discussed in this paper, the view that "Any consideration of the role of science education must begin not with an internalist view of its content and curricula, but rather with an *externalist perception of the society* it serves" (Osborne, 2003, p. 42, italics mine), should be complemented with the perception of the self. This is an important message for science teachers if they want to encourage involvement.

The second implication concerns the notion of meaningfulness. Although this notion is frequently evoked in the context of science education - since making school science meaningful for students is self-evident - it should be made clear that the object of study becomes meaningful when it is connected to the self of the student, when there is an involvement of the self. In view of this, we need to reconsider the notion of relevancy, and more specifically the idea that what is relevant to a student is necessarily meaningful to him/her. It can be argued that trying to understand the involvement of the self simply as "relevant content" or “relevant activities” is as misleading as trying to understand overpopulation in terms of population density. Even if an interest is developed (e.g., during flashy demonstrations, during participation in a community project) this is no guarantee about the development of a relation to the object of study. On the other hand, and in connection with was said above, we need to rethink two notions: “meaningful learning” and “science-as-fun”. “Meaningful learning” - which has been defined as rich conceptual ecology (see Novak, 1991; Novak & Gowin, 1984; Toulmin, 1972) – needs to be expanded and include the notion of self. Students need to be helped to perceive their own self within a conceptual ecology – i.e., within that pattern of concepts, like in a concept map – in order to create existential meaning (Hadzigeorgiou, 1997). The notion of “science-as-fun” also should be given more serious thought. Although school science can and should be fun, it is important that the significance of the object of study (i.e., an idea, an issue) be grasped by the students. The point that needs to be made is not just that fun should be a means and not an end in itself (although it can be both a means and an end), not just that there is a possibility of dichotomizing “fun” and “real science” (see Appelbaum & Clark, 2001), but that in having fun, students should be emotionally involved with both the activity they engage in and their actual object of study, and also grasp the significance of the latter.

In regard to the idea of making the natural world students’ larger object of study (in order to encourage respect for it), and to that of the awareness of the significance of that object, the move away from what Harvey (1989) called the "ontological reversal" - the process whereby mathematical abstractions take on a higher ontological status than the experience itself - is another important implication to consider. While acknowledging the crucial importance of modeling in school science education, it is important that the object being modeled is also kept in focus. Starting the teaching-learning process not with a hands-on activity, or with some technological applications, but from natural phenomena as the real sources of wonder, is an important idea to think about. Instead of giving batteries, wires, and light bulbs in order to introduce concepts and ideas from current electricity, for example, the teacher can evoke and incite awe and wonder by encouraging students, and especially young children, to observe spectacular natural phenomena (e.g., on video students can watch lightning), by helping them become aware that phenomena such as these are significant since they are involved in our own existence (e.g., our own body, the things we smell and touch). Thus the students are helped to see things in new light. As Witz (1996) points out, it would be more important to bring into focus the rich nature of a natural phenomenon than to focus merely on theoretical principles and/or technology connected with them.

> *The actual phenomenon or object – be it a manifestation of electricity, or the anatomy of the body, or the group behavior of chimpanzees – is the real source of wonder [….] Focusing on the actuality of the phenomenon, with its richness along many dimensions of human experience and its extraordinary wholeness, is not incompatible with a goal of 'cultural literacy' or 'understanding of mechanisms'. […] For this purpose, a study of the more natural and less technological manifestations of electricity and magnetism which fascinated the early investigators might be preferable, with gradual extension to construction of simple prototypes of electrical apparatus only a few years later, and 'real' electricity and magnetism later.* (Witz, 1996, pp. 601-602)

Apparently these ideas have important implications for early childhood science education. In considering the development of scientific literacy in the context of Science/Technology/Society/Nature, or in general the development of holistic/ecological curricula (see Hodson, 2003; Slattery & Rapp, 2003), the experience of wonder by young children can lead to a respect for Nature. In posing the question "How significant is the natural world for students?", one will inevitably seek ways to develop in young children an awareness of the significance of Nature itself. Apparently this idea of experiencing wonder has also implications for environmental education, since it is in the context of the latter that the question "How significant is the natural environment for students themselves?" becomes really crucial. For it is true that while students have knowledge of the importance of the natural world (i.e., they can tell you that it is important to protect the environment), the emotional significance of that world – a prerequisite for sociopolitical action or praxis – is much more difficult for them to develop (obviously due to the fact that they live away and separately from Nature, and also due to the primary role that technology plays for their lives and in their education). The experience of a sense of wonder in regard to natural phenomena has the potential to lead to an awareness of the significance of, and respect for, the natural world.

In connection with wonder the idea of inspiration also deserves some attention since it has important implications for the role of the teacher. Over the last decade the idea of science as another world (Costa, 1995), another culture (or subculture), has been stressed from the cultural perspective on science education (see Aikenhead, 1996, for a comprehensive review of the cultural perspective). Although the teacher can be viewed as a "tour guide", who introduces students into the culture of science (Aikenhead, 2002), the notion of teacher as someone who inspires, also may be considered very useful. Teachers can inspire students by revealing the mysterious nature and the wonder of both natural phenomena and scientific ideas, by helping them see and appreciate their beauty. Why should any student decide to cross into a foreign land, that is, science, even when a tour guide is always available? Making the decision to cross into a new, unknown, different, territory requires some inspiration, and the teacher's role here is very important. If inspired, students can be empowered. Empowerment and inspiration in fact can complement each other, an idea that needs to be taken into account even in the case of teaching marginalized group of students.

It should be pointed out here that the appropriation of concepts from cultural anthropology has helped science educators understand several problems associated with the teaching and learning of science as a culture. However, there are some questions to be asked: Is science a culture that is beyond most students' grasp? Are border crossings extremely difficult, if not impossible, for some students? Are the obstacles to learning science only cultural (or simply epistemological)? In the case of female students, to take, as an example, a group of “outsiders”, several factors can be identified in regard to their negative attitudes toward school science: less encouragement from teachers and parents, fewer out-of-school activities, lack of peer support, lack of good role models (see Brickhouse, 1994). This means that if girls had more encouragement, more out-of-schools science-related activities, more peer support and good role models they could make the border crossing into the culture of science. The same, of course, could be true for some boys, although not in the same degree. But how about encouraging an existential relationship between those girls and their object of study? How about helping them feel a sense of wonder? How about inspiring them? What about helping them to become aware that scientific knowledge is not only for power – not only to dominate and control the natural world - but also for love (see Taylor, 1998)? Empirical research into the aesthetic dimension of science learning and into the role of the teacher as one who inspires students to cross borders needs to done.

It is evident that these implications point to a reexamination and perhaps a reconsideration of many student-centered and socially oriented approaches to humanistic science education on the grounds that they (approaches) do not encourage the involvement of the self. They also point to an important message: science curriculum and instruction should not just make school science attractive; they should encourage deeper involvement of the self so that personal development and the achievement of social goals become a possibility. The challenges that emerge from this message are apparently great. However, for science teachers’ role the challenges are great too. Helping students to achieve the right tension between being curious about the natural world and feeling a sense of wonder, between their love and respect for the natural world and their curiosity to study it and to treat it empirically, between their personal identity and their vision for the development of their identity as a planetary species, are indeed great challenges. But as Ann Howe (1971, cited in DeBoer, 1991, p. 179) said,

> *The world needs people who can think* and *feel; people who know the earth and also love it; who know much about the forms of life and respect all life; who know what the stars are made of and can still look up at them and wonder.*

A reexamination of the role of science classroom also deserves attention. The idea of the significance of students' object of study points to the importance of discussion in the science classroom. More specifically, the awareness of the significance of science ideas and socio-scientific issues for students' personal life, and the larger significance of these ideas and issues necessitate moving beyond hands-on activities. Although a curriculum could be organized around key science ideas (see Millar & Osborne, 1998) and STS issues – in fact this is one form of organization that emerges from the conception of science education that I outlined here – this organization is no guarantee for the development of such an awareness. Moreover, the idea of significance points to a science education for all students. Should not all students develop an awareness of the significance of what they are supposed to study? Given the ideas of identity-making and "education as a possibility", all students should become aware of the significance of their object of study, and hence encouraged to develop a relationship between their own self and that object. This relationship can promote personal development (see Phenix, 1982, p. 311), which can be used as a strong argument behind the rhetoric of "Science for All".

This rhetoric, of course, brings me to another important implication: if "Science for All" is a vision and not just a slogan, then it should provide guidance for science education for all students. Therefore, the achievement of an important goal, that is, attracting the next generation of scientists, science educators and science teachers, should not be overlooked. This, in turn, means that opportunities for identity-building should be provided early on by considering the crucial role of scientific knowledge in that process of identity-building. Richard Feynman is quite explicit about this:

> *Hardly anyone can understand the importance of an idea, it is so remarkable. Except that, possibly, some children catch on. And when a child catches onto an idea. . . we have a scientist. These ideas do filter down . . . and lots of kids get the spirit – and when they have the spirit you have a scientist. It's too late for them to get the spirit when they are in our universities, so we must attempt top explain these ideas to children.* (Feynman, 1964, p.6)

Apparently, all of the above have important implications for science teacher education programs. These programs need to be designed in closer collaboration with the humanities. They should include philosophical readings, especially in aesthetics and phenomenology. Notwithstanding the importance of epistemology, science educators need to consider not only “scientific knowledge”, and more specifically, what counts as scientific knowledge and the criteria of its justification (that is, the main focus of epistemology), but also the process of scientific understanding itself (see Kosso, 2002). This process, as has already been pointed out, has a personal dimension that could be best described as aesthetic (Kosso, 2002; Root-Bernstein, 1996; 2002; Tauber, 1996), but which is missing from present science methods courses.

CONCLUSION

> *Science and science education [should be re-oriented] by encouraging a fundamental relation to the object of study which is part of a larger, deeper groundedness of the individual in regard to life and the universe and their meaning.* Witz (1996, pp. 600-601)

The four ideas that I discussed in this monograph need to be seriously considered if school science education is to be approached from a humanistic perspective. Although I would have liked to be more synoptic, my holistic approach would not do justice to those ideas and also to the complex issues raised by them. Their discussion points to a reexamination and perhaps a reconsideration of many student-centered and socially oriented approaches to science education on the grounds that they do not encourage a deep involvement of the self. This reconsideration though does not mean that science educators and curriculum designers will have to muse about the notions of self and identity, which, as one might argue, are ambiguous (i.e., the notion of self) and problematic (i.e., the notion of identity). It does mean though that they keep the notion of self and the involvement of the self in focus, since it is the involvement of the self that promotes personal development and the achievement of social goals. Witz's (1996, p. 599) comment, which I have already quoted, should provide science educators with some food for thought:

> *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.*

The problems that I discussed in regard to the process of the involvement of the self, point directly and indirectly to the limitations of the outlined conception of humanistic education. However, <u>the idea that classrooms are places in which all possibilities exist until a student chooses to actualize one of them</u> (see Liston, 2001) provides hope that <u>all</u> students can achieve worthwhile and humanistic goals in science education.

The goals of educating for citizenship and for sociopolitical action are no doubt laudable, but the effort to achieve them should not downplay the importance of personal development as a goal of education, which should be also promoted by science education. There is a serious question about whether the new perspective on science education, with an emphasis on the utility of scientific knowledge (Jenkins, 1997, 1999; OECD, 2000; Roth & Lee, 2004; UNESCO, 2000), can promote personal development, let alone a deeper involvement of the self. From a humanistic perspective, science education should do more than provide students with skills for problem solving (see Parkinson, 1986), for using scientific knowledge and making informed decisions.

One, of course, might seriously question whether the decision-making skills that students develop in school can be used in making decisions in the wider context of society. For the important decisions concerning the kind of research that is to be pursued, and the kind of technological applications that are to be given priority are not made by citizens. But even if such informed decisions were made by citizens, what kind of science education would be required? More likely a science education based not upon a narrow utilitarian/instrumentalist view of knowledge, but upon a wider one. Whether in the end decisions are made on political, scientific or technological grounds, values do play a major role (see Bell & Lederman, 2003), and science education ought to develop in students such values. The wise utilization of scientific and technological knowledge necessitates a science education that is based on a wider view of knowledge, which includes cognitive, ethical, moral, and aesthetic elements. Snow (1969) had been right in thinking that science and technology are the only means to prosperity, but history does testify to the fact that more than science and technology is required. These ideas point to a more holistic conception of science education.

Such a holistic conception should be based on an integration of scientific knowledge, with personal relevance and meaning, and social/global responsibility (see Hadzigeorgiou, 2005c). This integration, of course, is not without problems (see Egan, 1997, 2005b), but the point is that these three elements or components of the curriculum are not so opposed to one another, if their connecting ring, that is, the human element, is kept in the foreground. Encouraging a deeper involvement of the self - by considering the crucial role that purpose, awareness of the significance of the object of study, and aesthetics play in this process - is a great challenge, but it can help students achieve the right tension between these components. This in fact could be considered the ultimate purpose of a humanistic science education. Even if this purpose is conceived as an ideal, and therefore unrealistic, it still represents a commitment to certain values, which should guide science educators and science teachers in their actions. It will be that commitment that will help the science education community to approach science education from a humanistic perspective. Otherwise it will pay lip service to, or simply trivialize, the notion of humanistic education.

Contemporary reality (see Slattery & Rapps, 2003) makes it evident that a holistic conception of science education is imperative. Although there are have been attempts at humanizing science education (e.g., Hadzigeorgiou & Konsolas, 2001; Newton, 1986; Stinner, 1995; Watts, 2001; Watts & Bentley, 1994), I contend that these are based upon a narrow conception of humanistic science education, in the sense that the do not explicitly address all three of the aforementioned components. A humanistic science education should do justice to students, as human beings, to science as field of study that has to say something about some matters of significance, and to the wider world.

In this sense, humanistic science education is not a soft option. Just as making a garden requires more than weed killers, making science education humanistic requires more than just abandoning its scientific, academic, authoritarian tradition. It requires commitment and rigorous work in the area of curriculum development and also in teaching. Above all, it requires belief in the idea of "education as a possibility".

Hurd (1998, 2002) urged for a reinvention of science education. The ideas discussed in this monograph, whether or not they point to such a reinvention is a matter of interpretation. But they do point to a number of important implications (as these were discussed or alluded to) for current practices in both school science education and science education research. I hope these ideas and issues will create debate, promote reforms, and encourage more research into the area of humanistic science education. In fact, one of the purposes of this monograph was to stimulate discussion and thus further the dialogue on humanistic science education.

REFERENCES

AAAS (1990). Science for all Americans. Scientific literacy. New York, Oxford: Oxford University Press.

Aikenhead, G. (1996). Science education: Border crossing into the subculture of science. Studies
in Science Education, 27, 1-52.

Aikenhead, G. (2002). Whose scientific knowledge? The colonized and the colonized. In W-M. Roth & J. Desautels (Eds.), Science as/for sociopolitical action (pp.151-166). New York: Peter Lang.

Aikenhead, G. (2003). Review of research on humanistic perspectives in science curricula. Paper presented at the 2nd ESERA Conference. Noordwijkehoot, Netherlands, August 19-23.
Alsop, S., & Watts, M. (1997). A model for informal learning about radiation and radioactivity. Science Education, 81, 633-650.

Apple, M. (1999). Power, meaning, and identity. New York: Peter Lang.

Appelbaum, P., & Clark, S. (2001). Science! Fun ? A critical analysis of design/content/evaluation. Journal of Curriculum Studies, 33, 583-600.

Bateson, G. (1979). Mind and nature. New York: Dutton.

Bateson, M. (2004). Willing to learn: passages of personal discovery. New York: Steerforth Press.

Bell, R., & Lederman, N. (2003). Understandings of the nature of science and decision making on science and technology based issues. Science Education, 87, 352-378.

Bonnett, M. (2000). Environmental concerns and the metaphysics of education. Journal of Philosophy of Education, 34, 591-602.

Bonnett, M. (2004). Retrieving nature. Oxford: Basil Blackwell.

Brickhouse, N. (1994). Bringing in the outsiders: The sciences of the future. Journal of Curriculum Studies, 31, 131-142.

Brickhouse, N. (2001). Embodying science: A feminist perspective on learning. Journal of Research in Science Teaching, 38, 282-295.

Brickhouse, N. (2003). Science for all? Science for girls? Which girls? In R. Cross (Ed.), A vision for science education (pp. 93-101). London & New York: RoutledgeFalmer.

Brophy, J. (1987, October). Synthesis of research on strategies for motivating students to learn. Educational Leadership, 40-48.

Brophy, J. (1999). Toward a model of the value aspects of motivation in education. Educational Psychologist, 34(2), 75-86.

Brown, B. (2004). Discursive identities: Assimilation into the culture of science and its implications for minority students. Journal of Research in Science Teaching, 41, 810-834.

Burbulis, N., & Linn, M. (2001). Science education and philosophy of science: Congruence or contradiction? International Journal of Science Education, 13, 227-241.

Bybee, R. (1993). Reforming science education. New York: Teachers College Press.

Bybee, R. (1997). Achieving scientific literacy: From purposes to practices. Portsmouth, NH: Heinemann.

Calabrese-Barton, A. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. Journal of Research in Science Teaching, 35, 379-394.

Calabrese-Barton, A., & Osborne, M. (2001). Urban girls' participation in formal science settings: Playing with identities and borders. Curriculum & Teaching, 16, 17-38.

Calabrese-Barton, A., & Osborne, M. (2002). Reconstructing the harsh world: Science with/for sociopolitical action. In W-M. Roth & J. Desautels, J. (Eds.) Science as/for sociopolitical action (pp. 167-184). New York: Peter Lang.

Capra, F. (1983). The turning point. London: Fontana.

Capra, F, (2002). The hidden connections: Science and sustainable living. London: Harper Collins.

Chevalley, C. (1996). Physics as an art: The German tradition and the symbolic turn in philosophy, history of art and natural science in the 1920s. In A. Tauber (Ed.), The elusive synthesis: Aesthetics and science (pp. 227-250). Boston and London: Kluwer.

Cobern, W. (1991). Worldview theory and science education research. NARST Monograph No. 3. Manhattan, KS: NARST.

Cobern, W. (1996). Worldview theory and conceptual change in science education. Science Education, 80, 579-610.

Cobern, W. W. (2000a). Everyday thoughts about nature: An interpretive study of 16 ninth graders' conceptualizations of nature. Dordrecht, Netherlands: Kluwer.

Cobern, W. (2000b). The nature of science and the role of knowledge and belief. Science & Education, 9, 219-246.

Costa, V. (1995). When science is "another world": Relationships between the worlds of family, friends, school and science. Science Education, 79, 313-333.

Cross, R. (1999). The public understanding of science: implications for education. International Journal of Science Education, 21, 699-702.

Cummins, J. (2003). Challenging the considerations of difference as deficit: Where are identity, intellect, imagination, and power in the new regime of truth? In P. Trifonas (Ed.), Pedagogies of difference: Rethinking education for social justice (pp. 41-60). London & New York: RoutledgeFalmer.

Dahlin, B. (2001). The primacy of cognition – or of perception? A phenomenological critique of the theoretical bases of science education. Science & Education, 10, 453-475.

DeBoer, G. (1991). A history of ideas in science education. New York: Teachers College Press.

Delpit, L. (1988). The silenced dialogue: Power and pedagogy in educating other people's children. Harvard Educational Review, 58, 280-299.

Dewey, J. (1934). Art as experience. New York: Perigree.

Dewey, J. (1938). Experience and education. New York: McMillan.

Dewey, J. (1966). Democracy and education. New York: The Free Press.

Dirac, P. (1963). The evolution of the physicist's picture of nature. Scientific American, 208(5), 45-53.

Doll, W. (1993). A post-modern perspective on curriculum. New York: Teachers College Press.

Donelly, J. (2004). Humanizing science education. Science Education, 88, 762-784.

Duschl, R. (1988). Abandoning the scientistic tradition of science education. Science Education, 72, 51-62.

Duschl, R. (1994). Research on the history and philosophy of science. In D. Gabel (Ed.), Handbook of research on science teaching and learning. (pp. 443-465). New York: McMillan.

Egan, K. (1990). Romantic understanding. Chicago: University of Chicago Press.

Egan, K. (1997). The educated mind. How cognitive tools shape our understanding. Chicago: University of Chicago Press.

Egan (2005a). An imaginative approach to teaching. San Francisco, CA: Jossey-Bass.

Egan, K. (2005b). Students' development in theory and practice: The doubtful role of research. Harvard Educational review, 75, 25-42.

Faraday, M. (1978). The chemical history of a candle. Cherokee Publishing Company.(First published in 1861.)

Forshay, A. (1970). Curriculum for the 70s: An agenda of invention. Washington, DC: National Education Association, Center for the Study of Instruction.

Franken, R. (2001). Human motivation. Pacific Grove, CA: Brooks/Cole.

Freire, P. (1998). Pedagogy of hope. New York: Continuum.

Gallagher, S. (1992) Hermeneutics and education. New York: SUNY Press.

Gallas, K. (1998). Sometimes I can be anything: Power, gender and identity in a primary classroom. New York: Teachers College Press.

Girod, M., Ran, C., & Schepige, A. (2003). Appreciating the beauty of science ideas: Teaching for aesthetic understanding. Science Education, 87, 574-587.

Giroux, H. (1992). Border crossings. Cultural workers and the politics of education. New York and London: Routledge.

Godon, R. (2004). Understanding, personal identity, and education. Journal of Philosophy of Education, 38, 589-600.

Greene, M. (1988). The dialectic of freedom. New York: Teachers College Press.

Greene, M. (2000). Diversity and inclusion. Toward a curriculum for human beings. In F. Parkay & G. Moss (Eds.), Curriculum planning: A contemporary approach (pp. 293-300). Boston, MA: Allyn & Bacon.

Gross, P., N. Levitt, & M. Lewis (Eds.) (1996). The flight from science and reason. New York: The Academy of Sciences.

Hadzigeorgiou, Y. (1997). Relationships, meaning, and the science curriculum. Curriculum & Teaching, 12, 83-90

Hadzigeorgiou, Y. (1999). Problem situations and science learning. School Science Review, 81, 43-49.

Hadzigeorgiou, Y. (2001). Some thoughts on the notion of purposeful learning. Educational Forum, 65, 316-326.

Hadzigeorgiou, Y. (2005a). Romantic understanding and science education. Teaching Education, 16, 23-32.

Hadzigeorgiou, Y. (2005b). Inclusive practice in science education: Fulbright Project - Part I: Theoretical framework. Unpublished paper, Department of Curriculum & Instruction, University of Northern Iowa, Summer 2005.

Hadzigeorgiou, Y. (2005c). Science, personal relevance and social responsibility. Integrating the liberal and the humanistic traditions of science education. Educational Practice and Theory, 27, 82-93.

Hadzigeorgiou, Y. (in press). Humanizing the teaching of physics through storytelling: The case of current electricity. Physics Education.

Hadzigeorgiou, Y. & Konsolas, M. (2001). Global problems in the curriculum: Toward a humanistic and constructivist science education. Curriculum & Teaching, 16, 29-39.

Harvey, C. (1989). Husserl's phenomenology and the foundations of natural science. Athens, OH: Ohio University Press.

Hassard, J., & Weisberg, J. (1999). The emergence of global thinking among American and Russian youth as a contribution to public understanding. International Journal of Science Education, 21, 731-744..

Head, J. (1997). Working with adolescents: Constructing identity. London: The Falmer Press.

Hirst, P. (1972). Liberal education and the nature of knowledge." In R. Dearden, P. Hirst, & R. Peters (Eds.), Education and the Development of Reason (pp. 391-414). London: Routledge & Kegan Paul.

Hirst, P. (1974). Knowledge and the curriculum. A collection of philosophical papers. London; Boston: Routledge and Kegan Paul.

Hodson, D. (2003). Time for action. Science education for an alternative future. International Journal of Science Education, 25, 645-670.

Holton, G. (1996). Science education and the sense of self. In P. Gross, N. Levitt, & M. Lewis (Eds.), The flight from science and reason (pp. 551-560). New York: The Academy of Sciences.

Hove, P. (1996). The face of wonder. Journal of Curriculum Studies, 28, 437-462.

Howe, A. (1971). A lost dimension in elementary science education. Science Education, 55, 143-146.

Hurd, D. (1998). Scientific literacy: New minds for a changing world. Science Education, 82, 407-416.

Hurd, D. (2002). Modernizing science education. Journal of Research in Science Teaching, 39, 3-9.

Jardine, D., Clifford, P., & Friesen, S. (2003). Back to the basics of teaching and learning. Mahwah, NJ: Lawrence Erlbaum.

Jenkins, E. (1994). Public understanding of science and science education for action. Journal of Curriculum Studies, 26, 601-611.

Jenkins, E. (1996). The "nature of science" as a curriculum component. Journal of Curriculum Studies, 28, 137-150.

Jenkins, E. (1997). Towards a functional understanding of science. In R Levinson & R. Thomas (Eds.) Science today. Problem or crisis? London: Routledge.

Jenkins, E. (1999). School science, citizenship and the public understanding of science. International Journal of Science Education, 21, 703-710.

Jenkins, E. (2000). Constructivism in school science education: powerful model or the most dangerous intellectual tendency? Science and Education, 9, 599-610.

Jenkins, E. (2002). Linking school science education with action. In W-M. Roth & J. Desautels, J. (Eds.), Science as/for sociopolitical action (pp. 17-34). New York: Peter Lang.

Kosso, P. (2002). The omniscienter: beauty and scientific understanding. International Studies in the Pihilosophy of Science. 16, 39-48.

Kozoll, R., & Osborne, M. (2004). Finding meaning in science: Life-world, identity, and the self. Science Education, 88, 157-181.

Kroger, J. (1996). Identity, regression, and development. Journal of Adolescence, 19, 203-222.

Krogh, L., & Thomas, P. (2005). Studying students' attitudes towards science from a cultural perspective but with a quantitative methodology: Border crossing into the physics classroom. International Journal of Science Education, 27, 281-302.

Lederman, N. (1998). The state of science education: Subject matter without context. Electronic Journal of Science Education,3, 2.

Lepper, M. (1988). Motivational considerations in the study of instruction. Cognition and Instruction, 5, 289-309.

Liston, D. (2001). Joy as a metaphor for convergence: A phenomenological and aesthetic investigation of social and educational change. Cresskill, NJ: Hampton Press.

Loving, C. (1995). Comments on universalism, multiculturalism, and science education. Science Education, 79, 341-348.

Loving, C., & Ortiz de Montellan, B. (2003). Good versus bad culturally relevant science. Avoiding the pitfalls. In M. Hines (Ed.), Multicultural science education (pp. 147-166). New York: Peter Lang.

Marcia, J. (1988). Common processes underlying ego identity, cognitive/moral development, and individuation. In D. Lapsley & F. Power (Eds.), Self, ego, and identity: Integrative approaches. New York: Springer-Verlag.

Maslow, A. (1971). The farther reaches of human nature. New York: Viking.

Maxwell, N. (1984). From knowledge to wisdom. Oxford: Basil Blackwell.

Maxwell, N. (1992). What kind of inquiry can best help us create a good world? Science Technology and Human Values, 17, 205-227.

McAllister, J. (1996). Beauty and revolution in science. Ithaca, New York: Cornell University Press.

Midgley, M. (2000). The need for wonder. In R. Stannard (Ed.), God for the 21st century (pp. 185-187). Templeton Foundation Press.

Miller, J. (1990). Holistic learning. Toronto: OISE Press

Newton, D. (1986). Humanizing science teaching. What is it? School Science Review, 67, 457-461.

Noddings, N. (1992). The challenge to care in schools: An alternative approach to education. New York: Teachers College Press.

Noddings, N. (1993). Educating for intelligent belief and unbelief. New York: Teachers College Press.

Novak, J. (1991). Clarify with concept maps: A tool for students and teachers alike. The Science Teacher, 58(7), 45-49.

Novak, J, & Gowin, B. (1984). Learning how to learn. New York: Cambridge University Press.

OECD (2000). Measuring Student Knowledge and Skills: The PISA 2000 Assessment of Reading, Mathematical, and Scientific Literacy. Paris: OECD.

Oliver, D. & Gershman, K. (1989). Education, modernity and fractured meaning: Toward a process theory of teaching and learning. Albany, NY: SUNY Press.

Olson, J., & Lang, M. (2004). Science and technology and the didactics of citizenship. Journal of Curriculum Studies, 36, 543-553.

Opdal, P. M. (2001). Curiosity, wonder and education seen as perspective development. Studies in Philosophy and Education, 20, 331-344.

Osborne, J. (1996). Beyond constructivism. Science Education, 80, 53-82.

Osborne, J. (2000). Science for citizenship. In M. Monk & J. Osborne (Eds.), Good practices in science teaching: What research has to say (pp. 225-248). Buckingham: Open University Press.

Osborne, J. (2003). Making science matter. In R. Cross (Ed.), A vision for science education (pp. 36-52). London & New York: Routledge Falmer.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. Journal of Research in Science Teaching, 40, 692-720.

O'Sullivan, E. (2002). The project and vision of transformative education. In E. O'Sullivan, A. Morrell & M. O'Connor (Eds.), Expanding the boundaries of transformative learning (pp. 1-12). New York: Palgrave.

Parkinson, G. (1986). Humanistic education. Some philosophical considerations. In R. Straughan (Ed.), Philosophers on education (pp. 93-106). Totowa, New Jersey: Barnes & Nobles.

Pekarsky, D. (1982). Dehumanization and education. Tecahers College Record, 84, 339-353.

Peters, R. (1966). Ethics and education. London: Allen and Unwin.

Peter, R. (1967). What is an educational process? In R. Peters (Ed.), The concept of education (pp. 1-23). New York: The Humanity Press.

Peters , R. (1973). Aims of education: A conceptual enquiry. In R. Peters (Ed.), The Philosophy of Education (pp. 1-35). Oxford: Oxford University Press.

Peters, R. (1977). Education and the education of teachers. London: Routledge and Kegan Paul.

Phenix, P. (1964). Realms of meaning. New York: McGraw Hill.

Phenix, P. (1971).Transcendence and the curriculum. Teachers College Record, 73, 271-283.

Phenix, P. (1982). Promoting personal development through learning. Teachers College Record, 84, 301-317.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. Review of Educational Research, 63(2), 167–199.

Polanyi, M. (1959). The study of man. Chicago: University of Chicago Press.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66, 211–227.

Postman, N. (1995). The end of education. New York: Alfred Knopf.

Pugh, K. (2004). Newton's laws beyond the classroom walls. Science Education, 88, 182-196.

Raffini, J. (1993). Winners without losers: Structures and strategies for increasing student motivation to learn. Boston: Allyn and Bacon.

Ramsden, J. (1998). Mission impossible? Can anything be done about attitudes to science? International Journal of Science Education, 20, 125-135.

Reveles, J., Cordova, R., & Kelly, G. (2004). Science literacy and academic identity formation. Journal of Research in Science Teaching, 41, 111-144.

Root-Bernstein, R. (1996). The sciences and arts share a common creative aesthetic. In A. Tauber (Ed.), The elusive synthesis. Aesthetics and science (pp. 49-82). Boston, London: Kluwer.

Root-Bernstein, R. (2002). Aesthetic cognition. International Studies in Philosophy of Science 16, 61-77.

Roth, W-M. (2003). Scientific literacy as an emergent feature of collective praxis. Journal of Curriculum Studies, 35, 9-23.

Roth, W-M. & Lee, S. (2002). Breaking the spell: Science education for a free society. In W-M. Roth & J. Desautels, J. (Eds.) Science as/for sociopolitical action (pp. 67-98). New York: Peter Lang.

Roth, W-M., & Desautels, J. (Eds.) (2002). Science education as/for sociopolitical action. New York: Peter Lang.

Roth, W-M., & Lee, S. (2004). Science education as/for participation in the community. Science Education, 88, 263-291.

Sarewitz, D. (1996). Frontiers of illusion: Science, technology, and the politics of progress. Philadelphia: Temple University Press.

Schank, R. (2004). Making minds less well educated than our own. Mahwah, NJ: Lawrence Erlbaum.

Scheffler, I. (1996). The concept of the educated person." In V. Howard & I. Scheffler (Eds.), Work, education, and leadership (pp. 81-100). New York: Peter Lang.

Schwartz, R., Lederman, N., & Crawford, B. (2004). Developing views on NOS in an authentic context. An explicit approach to bridging the gap between NOS and scientific inquiry. Science Education, 88, 610-640.

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. Educational Researcher, 34(4), 14-22.

Slattery, P. (1995). Curriculum development in the postmodern era. New York: Garland.

Slattery, P., & Rapp, D. (2003). Ethics and the foundation of education. Boston: Allyn & Bacon.

Snow, C. (1969). The two cultures; and a second look. London: Cambridge University Press.

Stinner, A. (1995). Contextual settings, science stories and large context problems: Toward a more humanistic science education. Science Education, 79, 555-581.

Southerland, S. (2000). Epistemic universalism and the shortcomings of curricular multicultural science education. Science & Education, 9, 289-307.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. Duschl & R. Hamilton (Eds.), Philosophy of science, cognitive psychology, and educational theory and practice (pp. 147–176). NewYork: SUNY Press.

Swartz, E. (1996). Emancipatory pedagogy: a post-critical response to 'standard' school knowledge. Journal of Curriculum Studies, 28, 397-418.

Tauber, A. (Ed.) (1996). The elusive synthesis: Aesthetics and science. Boston and London: Kluwer.

Taylor, C. (1991). The malaise of modernity. Concord, ON: Anansi Press.

Taylor, J. (1998). Poetic knowledge. The recovery of education. New York: SUNY Press.

Toulmin, S. (1972). Human understanding: An inquiry into the aims of science. Princeton, NJ: Princeton University Press.

Toulmin, S. (1976). Knowing and acting. An invitation to philosophy. New York: McMillan

Tyson, L. M., Venville, G. J., Harrison, A. G., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. Science Education, 81, 387–404.

UNESCO (1993). International Forum on Scientific and Technological Literacy for All. Final Report. Paris: UNESCO

UNESCO (2000). Report of the world conference on science: Framework for action. Science Sector, Paris: UNESCO.

Verhoven, C. (1972). The philosophy of wonder. New York: McMillan.

Waterman, A. (1992). Identity as an aspect of optimal physiological functioning. In G. Adams, T. Gullotta, & R. Montemayor (Eds.), Adolescent identity formation (pp. 121-176). Newbury Park, CA: Sage.

Waterman, A. (1993). Two conceptions of happiness. Contrasts of personal expressiveness and hedonic enjoyment. Journal of Personality and Social Psychology, 64, 73-80.

Watts, M. (2001). Science and poetry: passion v. prescription in school science? International Journal of Science Education, 23, 197-208.

Watts, M., & Bentley, D. (1994). Humanizing and feminizing school science. Reviving anthropomorphic and animistic thinking in constructivist science education. International Journal of Science Education, 16, 83-92.

Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. Cambridge, UK: Cambridge University Press.

Witz, K. (1996). Science with values and values for science. Journal of Curriculum Studies, 28, 597-612.

Wong, D., Pugh, K., and the Dewey Ideas Group at Michigan State University (2001). Learning science: A Deweyan perspective. Journal of Research in Science Teaching, 38, 317-336.

Woolnough, B. (1998). Learning science is a messy process. Science Teacher Education, 23, 17.