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Engaging Students in Science: The Potential Role of "Narrative Thinking" and "Romantic Understanding"

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Engaging students in science and helping them develop an understanding of its ideas has been a consistent challenge for both science teachers and science educators alike. Such a challenge is even greater in the context of the "Science for All" curriculum initiative. However, Bruner's notion of "narrative thinking" and Egan's "romantic understanding" offer an alternative approach to teaching and learning science, in a way that engagement and understanding become a possibility. This chapter focuses on students' "narrative mode of thought," as a bridge to understanding science—which has traditionally been based more upon the use of logico-mathematical thinking in the upper grades—and on a distinctive form of understanding the world, characteristic of students of the age range from 8 to 15 years. This latter form of understanding, that the educational theorist Kieran Egan calls "romantic understanding," has features that can be readily associated with the natural world and its phenomena. Therefore its development could be fostered in the context of school science learning, and in a way that the narrative mode would also be taken into consideration.

Keywords: science, engagement, narrative thinking, romantic understanding, story, language

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INTRODUCTION

Science as a school subject to be taught and learned, has always presented a challenge to both teachers and students. On the one hand, understanding science (as content, inquiry and process skills) is a challenging task for students, as it involves a construction process, which is complex and iterative—not a linear one—and which also takes time and effort. An important implication of this construction process, as constructivist-oriented research in the 1980s and 1990s showed, is the possibility for students to *construct* not only a conceptual framework that lacks the coherence of true scientific knowledge, but to equally construct alternative ideas that are different from the canonical scientific ones. Other implications that were discovered is that the construction process is influenced by several interrelated factors, such as students' prior conceptions and views on the nature of science (their epistemologies—Kalman, 2008/2017; Matthews, 2015), their interest and motivation, the classroom culture, the opportunities they have for social interaction, dialogue, and argumentation, the generation of representations (for the use of modeling and analogies), and also their opportunities for cognitive dissonance and conceptual change, as well as for applying new knowledge to new contexts (Resnick, 1983; Hadzigeorgiou, 1997, 1999, 2015; Stefanich and Hadzigeorgiou, 2001; Tytler et al., 2013).

On the other hand, teaching science is a challenging task for teachers, because, in addition to providing students with opportunities for constructing scientific understanding, they have to primarily engage and motivate students with science, its content and techniques (e.g., concepts, equations, laws, and laboratory skills). For it is obvious that without some degree of engagement, understanding cannot truly take place. Even though some degree of understanding may very well motivate students to learn, the initial engagement with science seems to be a prerequisite for understanding and long-term learning. And needless to say, motivation on the part of students to learn does not guarantee an understanding of science, especially science content (Hadzigeorgiou, 2005a, 2015).

Thus, at least as far as school science education is concerned, one can very well talk about a two-fold challenge: how can students be engaged with science content—but in a way that true understanding of science could also become a possibility? This paper will discuss the possibility of engagement with science content learning by focusing on the potential of two ideas, namely, "narrative thinking" and "romantic understanding." But first a look at the problem of engagement itself, which is central to the teaching/learning process, and, as such, central to the process of understanding science.

THE PROBLEM OF STUDENTS' ENGAGEMENT WITH SCIENCE CONTENT KNOWLEDGE

The problem of how to engage students in science, as mentioned, has always been challenging and pressing. Even though engagement does not necessarily entail, or result in, understanding, especially when it comes to the case of learning science, engaging students in science is a prerequisite for understanding. However, what may not be obvious is that the process of engagement itself is a complex one. Even though engagement may very well be encouraged by students' *interest,* there are other key factors which are also involved, such as personal identity, maturity, purpose for learning science, and students' awareness of the significance of the object or topic of study. Such factors can influence to a large extent, or may even determine, students' engagement with science (Hadzigeorgiou, 2005a; Hadzigeorgiou and Stivaktakis, 2008). Furthermore, the variety of ways in which the term "engagement" has been interpreted in the literature poses an additional problem in regards to what the findings of the various studies on student engagement really mean. As Godec et al. (2018) point out, engagement has been construed as enjoyment and interest, but also as motivation toward science, as well as future orientations toward science. Moreover, it has been taken to mean the degree (frequency) of students' participation in science related activities, as well as intensity of such participation.

Although a conceptual clarification of the notion of engagement is beyond the scope of this paper, it is important nevertheless to accentuate here that "engagement" should not be conflated with the *motivation* to learn. Even though the two terms could be used interchangeably—and in fact they often are—there is a subtle and nonetheless important difference between them. For there has always been a question about whether students' motivation for learning resides mainly in students' object of study *per se*, that is, the content and/or the processes of science, or if in fact other factors are involved (Hadzigeorgiou and Stivaktakis, 2008; Hadzigeorgiou, 2012; Hadzigeorgiou and Schulz, 2014, 2017). Indeed, it is quite evident that students can be motivated to participate in learning activities but for reasons that may vary and where their motives primarily reside in things other than the immediate topic of study (e.g., involving such factors as teaching style and teacher personality, humor, peer social interactions in group activities, flashy demonstrations, etc.). Furthermore, the notion of engagement should not be conflated specifically with the notion of student "interest" either. Apart from the conceptual problems inherent in the notion of interest itself, there is empirical evidence that what students think is interesting (e.g., a topic, an issue, an idea) does not necessarily motivate them to study it, let alone to study it further—that is, to try to learn more about it and move beyond the class situation (Hadzigeorgiou and Schulz, 2017).

Thus, there is a *distinction* to be made between peripheral things involved in pedagogy (albeit linked to content knowledge), that are supposedly interesting and motivating, and the actual or intimate engagement with the students' personal scientific object of study, namely content and processes. And such a distinction is a crucially important one: the reason being that this engagement *with* the actual science content has the potential to discourage what the American philosopher of education Dewey (1934, 1966) had previously called the "spectator theory of knowledge." What he meant was the dualistic learning framework that created an emotional-cognitive gap between the *subject* (the student) and the *object* (content) that could very well be fostered by, and inherent to, common instructional sequences and curricula. And this despite the reform initiated "constructivist" and "guided inquiry" intentions of both teachers and curriculum designers (see Dahlin, 2001; Hadzigeorgiou, 2005c, 2016). For example, a dualistic learning framework can be unknowingly encouraged by science teachers when (as one of their main instructional strategies) they try to figure out how to "sugar-coat" difficult science ideas and topics (like the mole concept in chemistry, or dynamics equations in physics) using flashy demonstrations, hence by focusing on peripheral things and not, as Pugh (2004) pointed out, on the science content itself.

The crucial importance of true engagement with science content can be seen in its potential to encourage the application of classroom learning in "free-choice" contexts, also the expansion of perception (that is, the ability to see objects, events, and issues *through* the lens of the science content), as well as an appreciation of the value of this content for its role in enriching everyday experience (see Pugh, 2011; Pugh et al., 2017). Certainly, such a learning experience with such characteristics may be considered ideal, and, to a certain extent it is. However, it deserves to be recognized that it is indeed a pedagogical possibility (see Hadzigeorgiou, 2016; section The Problem of Students' Engagement with Science Content Knowledge). In this paper though, as was previously said, the focus will be on two ideas, namely, the narrative mode of thinking and the romantic mode of understanding, with the focus on their potential to encourage engagement *with* science content. Moreover, if it is indeed true that personal engagement with a school subject, like science, has the potential to take the science knowledge (i.e., what students learn at school) beyond the walls of the classroom, and equally if it has the ability to transform one's outlook on the world—which some philosophers of education, physicists and cognitive scientists identify with significant learning (Feynman, 1968; Hirst, 1972; Hadzigeorgiou, 2016)—then the problem of how to engage and motivate students with actual science content should become a central concern for school science education.

NARRATIVE THINKING AS A BRIDGE TO UNDERSTANDING SCIENCE

No doubt science can be an exciting subject, yet a difficult one to teach, simply because science, as both a body of knowledge and a way of reasoning or thinking, is different from everyday knowledge and thinking (leaving aside the linkage to science as a mode of experimental inquiry). Even though the viewpoint that scientific thinking is a refinement of everyday thinking contains an element of truth, this refinement process nonetheless, in the case of students, as research evidence suggests, takes time and requires specific strategies (Stefanich and Hadzigeorgiou, 2001; Hadzigeorgiou and Fotinos, 2007; Schulz, 2009). Central to this process of understanding has been the use of what can be called logico-mathematical reasoning, that is, "logico-scientific" thinking (Bruner, 1986, p. 12), which is responsible for the formation of hypotheses, the development of arguments, creative modeling, the solutions of problems, the descriptions and construction of systems and their inter-relationships (Piaget, 1970; Bruner, 1986; Giere, 1991). Secondary and tertiary science education is known to make use of inductive-empirical and hypothetico-deductive variations of scientific reasoning (Cawthron and Rowell, 1978; Duschl, 1994), though it tends to become overly simplified and known to degenerate into talk of a "step-wise scientific method" supposedly used by all scientists, which is a myth (Bauer, 1992).

However, not all thinking is like this, when humans seek to understand and interpret the world around them. It was this observation which led, in the mid-1980s, the psychologist Jerome Bruner to propose another kind of thinking that is not predominately logical, mathematical, abstract, and seeks to construct and model ideal systems. Bruner's observations (1985; 1986), as a forerunner of the "cognitive revolution," were based on common experience and empirical evidence.

> *There are two irreducible modes of cognitive functioning—or more simply, two mode of thought—each meriting the status of a "natural kind". Each provides a way of ordering experience, of constructing reality and the two (though amenable to complementary use) are irreducible to one another (p. 97).*

According to Bruner (1985), the status "natural kind" refers to the fact that each mode of thinking comes spontaneously into being, and always under minimal contextual constraint. These two modes Bruner called *paradigmatic* (or logico-mathematical) and *narrative*. The former is concerned with the formation of hypotheses, the development of arguments, solutions to problems, finding proofs, and with rational thinking in general. According to Bruner (1986, p. 12), it fulfills "the ideal of a formal, mathematical system of description and explanation" by employing "categorization or conceptualization and the operations by which categories are established, instantiated, idealized, and related to one another to form a system." The latter, on the other hand, is concerned with what Bruner calls "verisimilitude," that is, life-likeness, and the creation of meaning. It seeks explications that are context sensitive and particular (not context-free and universal). It is entirely divergent—in sharp contrast to paradigmatic mode, which is convergent—and employs literary devices, such as stories, metaphors, similes, even hyperboles, in order to create meaning. In looking at those two modes of thinking, it is quite evident that while the paradigmatic mode is about "logico-mathematical thinking" *per se*, the narrative mode is about people (i.e., human emotions, ambitions, intentions, successes and failures, human actions, and experiences). In other words, while the paradigmatic mode presupposes distancing oneself from emotions and the human element in general, the narrative mode presupposes personal involvement with the object of thought. However, according to Bruner (1985, 1986), the two modes are complementary.

But what does the narrative mode of thinking have to do with science, that is, a field of study characterized by logical analysis, and which (field) has been developed as a result of logical arguments and scientific explanations (e.g., in the form of hypotheses, mathematical models and theories)? To answer this question one has to consider the fact that many scientific (and mathematical for that matter) hypotheses did indeed start their lives as stories and metaphors (Hadzigeorgiou, 2016). This view is in line with the one held by the philosopher of science Popper (1972), who argued that today's science is built upon the science of yesterday and that the older scientific theories were built upon "prescientific myths" (p. 346). Thus, the narrative mode of thinking can be considered equally important to science.

One can, of course, very well argue that the narrative mode of thinking (as the source of the creation of a myth or a story) can result in the construction of unreal or even impossible worlds. However, as Bruner (1985) points out, "the narrative mode is not as unconstrainedly imaginative as it might seem to the romantic" (p. 100). In science, therefore, the constructions that result from the use of the narrative mode cannot just refer to any kind of world (or reality), or even to all kinds of impossible worlds. The reason is that the paradigmatic (or logico-mathematical) mode of thinking, as a mode of thinking that is inextricably tied to the real world of things, does test concepts and ideas (i.e., the constructions of the narrative mode) through the use of evidence, experimentation, argumentation, and so on. Nonetheless, Bruner's hypothesis about the existence of the two modes of thinking, although a bold one, does shed light on the development of scientific language and knowledge, which cannot be explained solely in terms of paradigmatic (logico-mathematical) thinking. Sutton (1996) in fact has illustrated how the language of a scientific concept changes from its initial formulation to how it later becomes rephrased, codified, and depersonalized through the different stages of publication—from original discovery to research paper, handbook and finally textbook—and uncovers the often neglected aspect of the development of scientific concepts themselves. In other words, the *historicity* of scientific language and theories. The original creative, speculative and often very personal narrative occurs when discoveries are made—"where wonder and curiosity abound"—and where the language can be figurative and even metaphorical (e.g., discovery of electron, DNA and quarks) during the early stages of research or "frontier science." However, by the time the much later stage of "textbook science" has been reached, the concepts and discoveries have been codified, often abstracted out of the historical matrix, while the language has shifted from narrative or lived-story to depersonalized transmission and exposition. Too many textbooks create the false impression that science does not start as an exciting, arduous exploratory process but rather arrives as a "finished product" whose ideas, facts and equations are to be memorized and manipulated (Stinner, 1995; Kalman, 2008/2017; Schulz, 2014b).

The interplay between the two modes of thinking, that has been central to the historical and philosophical development of science, has been also empirically documented in the context of school science education (Kurth et al., 2002). It is indeed this interplay between the two modes of thinking, that is, the narrative and the paradigmatic, which helps children to make sense of the natural world. But whether the two modes of thinking are really as mutually exclusive as Bruner (1985, 1986, 1990) hypothesized, is debatable, and not our concern here. And yet the very nature of "final form science" as codified in language of increasing technicality in textbooks at the upper grades, reinforces the problem of engagement, as they further distance the student from the object of study.

It should be noted at this point that the importance, in fact the centrality, of the narrative mode of thinking is captured in the notion of "mind as a narrative concern" (Sutton-Smith, 1988). Such a notion can help explain not only the "irrational character" of some kinds of scientific thinking (Kuhn, 1970; Feyerabend, 1993; Di Trocchio, 1997), but also the creation of scientific ideas that necessitated mental leaps, even "jumps of the imagination," also famous thought experiments, which could not have become possible only through strictly logical causal-type thinking (Hadzigeorgiou, 2016). In addition, such a notion can help explain certain facts, which are important to consider when approaching the general problem of student engagement with science. One such fact, has been pointed out by White (1981, p. 1): despite the fact that people are not capable of understanding "the specific thought patterns of another culture" they have "less difficulty understanding a story coming from another culture, however exotic that culture may appear." Another fact—and this is crucially important when it comes to the problem of engaging students in science—is that the narrative mode of thinking is used by people in everyday life. Indeed people of all ages use their narrative mode not only to make sense of their experiences, but also to communicate and to plan their future actions (Bruner, 1990). And this is why Bruner (1991), called the narrative mode, the "default mode" of thinking. If this is true, then the argument that people are, or become more, competent at thinking in the narrative mode, in comparison with thinking with the logical mode (Hadzigeorgiou, 2016), can provide food for thought when it comes to planning for curriculum and instructional sequences, which consider the students' own inclination toward a narrative mode of thinking.

In his *The Storytelling Animal. How Stories Make Us Human*, Jonathan Gottschall provides a compelling argument that we are storytelling animals because of evolutionary reasons (Gottschall, 2012). His argument is based on research in psychology, neuroscience, and evolutionary biology. Even if one remains skeptical about what specific scientific studies Gottschall has drawn upon in order to advance his argument (e.g., does reading fiction cause people to modify or change their attitudes and behavior?), there is still plenty of evidence from a variety of experiments that seems to support Bruner's (1985; 1986) hypothesis about the narrative mode of thinking. In addition, Gottschall's work also supports Egan's (1997, 2005) work on the development of the "educated mind". It is of note that Egan transcended some dilemmas regarding the development of the mind by focusing neither on knowledge *per se* nor on child psychology, but instead on the notion of "cognitive tool," that is, a tool that facilitates thinking and understanding. Cognitive tools are picked up by children as they grow up and become socially enculturated through a language community. One such tool is "story," and the educational process could be conceived, according to Egan (1997), as a process that provides students with an array of cognitive tools, which (tools) are also associated with particular *kinds of understanding*—more broader and general socio-cultural tools (see also next section in this chapter).

The implications of narrative thinking is that narratives and especially stories become indispensable teaching/learning tools. Indeed narratives and stories can be used for communicating important ideas *of* and *about* science. This mode of introducing students to science is engaging for a number of reasons. First, "narratives and stories are more appropriate in describing what we learn about the world" (Hadzigeorgiou, 2016, p. 90), according to research based on the constructive nature of human sense- and meaning-making (see also Egan, 1986, 1988, 1999). Second, narratives, particularly those produced by the students themselves, can foster science learning, by bridging the gap between students' everyday knowledge (and quite frequently naïve conceptions) and scientific conceptions (Zabel and Gropengiesser, 2015). Only through dialogue and the opportunity to partake of using science language in specific class settings can the so-called "three language problem" (i.e., specialist science language, everyday language, science education language), be gradually overcome, according to recent socio-linguistic-based research (Wellington and Osborne, 2001; Yore and Treagust, 2006; Schulz, 2014b). Third, narratives and stories can be considered the means of translating "knowing into telling" (Avraamidou and Osborne, 2009, p. 1,012), an idea that is crucially important in science education, where abstract scientific knowledge must be presented in a meaningful way to the student.

Fourth, stories provide the context for a "silent" dialogue between the teller and the listener, which, by its very nature, is engaging. According to Solomon (2002), a story can be considered as a dialogue. Indeed, despite the fact that the student/listener does not actively participate in the telling of the story, she/he tries to create meaning by listening attentively to the story. Finally fifth, narratives and stories have the potential to break barriers and dichotomies between epistemic subject and epistemic object, something that has been stressed from both a post-modernist perspective on teaching and learning, and a hermeneutic approach (Kalman, 2011; Schulz, 2014b; Although a strong caution should be brought to bear when some post-modernist perspectives are employed in science education; Nola and Irzik, 2005; Schulz, 2007). Indeed, from such a post-modern perspective, understanding the world involves a rejection of traditional stark dichotomies, like those between fact and fiction, reality and epistemic subject. Gough (1993) has convincingly argued for a pedagogy, which "tacitly embraces [...] the relatedness of the observer and the observed and the personal participation of the knower in all acts of understanding" (p. 607). Likewise from a hermeneutic perspective, meaning-making through language and interpretation is seen to be prerequisite for any understanding to take place at all, which involves the learners' very *being* involved in an interpretive act (a form of *intersubjectivity*) between knower and object, in contrast to knowledge "possession" by isolated individual cognition, according to the standard (epistemological) spectator theory of knowing (Eger, 1992). Borda (2007) has even suggested how some Hermeneutic *dispositions* (doubt, humility, strength) could be fostered in science learners to increase their engagement, to help overcome the textbook content-based and classroom-based language barriers, and approach science as a hermeneutic endeavor[1] [see also Kalman (2008/2017, 2011), on the advantage of "reflective writing" when using the "hermeneutic circle method" in tertiary physics and engineering classes].

It should be noted that narratives and stories can be very engaging (compared with other teaching methods), not only because students become emotionally involved with content knowledge on a deeper level, but also because they have the benefits of experiential learning due to high levels of the listeners' active engagement. Moreover, narratives and stories can appeal to a wide range of intelligences as well as a variety of learning styles (see Hadzigeorgiou, 2016). It should also be noted that storytelling, in particular, satisfies all three elements of effective learning, based on brain-based research (Caine et al., 2005, p. 233): (a) *Relaxed Alertness* (i.e., a state of mind created in a low-threat atmosphere, which also creates a sense of community), (b) *Planned Immersion* (i.e., the creation of an environment in which students become involved with the objectives of the lesson) and (c) *Active Processing* (i.e., utilization of learning methods, which encourage reflection and integration of the information in a meaningful way)[2].

In light of the above, narrative thinking becomes indispensable if engagement with science content is itself a main goal of pedagogy. This, in turn, means that narratives and stories can play the role of bridges to the world of science, between the learner, and the science content. Narratives and stories can introduce students to science content ideas and to ideas about the *history and nature of science* (NoS), if these ideas are embedded in the narratives and the plot of the stories, and especially if the actual historical background is respected (Allchin's warnings signs about using pseudohistory and pseudoscience is to be heeded, 2013). The empirical evidence thus far, although limited, is quite encouraging (see Hadzigeorgiou, 2016, for a review of studies on the use of narratives and storytelling in science education). Certainly there are some limitations to be considered, according to Hadzigeorgiou (2017)—e.g., narrative explanations are more suitable for the historical sciences, like geology and cosmology, and for unique events, like the disappearance of dinosaurs, whereas it is difficult to create narratives for all phenomena and for all science concepts because of the need to use deductive and descriptive explanations. While these can be presented in a narrative form, possibly also through the use of anthropomorphism, but these are more suitable for younger children. But it is their potential to engage students emotionally and cognitively that we should keep them in mind, and the instructional sequences that we design should take this potential into consideration, too. In particular, special attention must be paid so that the narratives and stories we create (fictitious or based on the history of science), should have specific features (i.e., narrative elements), according to the literature on narratives (see Klassen and Froese-Klassen, 2014a). Such caution is more readily understood in the case in which one seeks to create a narrative or a story with "romantic features," with the aim of fostering in students a *romantic understanding* of science (Hadzigeorgiou et al., 2012). This we discuss in the next section.

"ROMANTIC UNDERSTANDING" AS A WAY TO BE ENGAGED WITH THE CONTENT OF SCIENCE

"Romantic Understanding" is a term coined by the educational theorist Kieran Egan, who used it to describe a kind or form of understanding that children develop approximately between the ages of 8 and 15 years. It is one of five *forms* of understanding that students can develop throughout their participation in the educational process of schooling. According to Egan's socio-linguistic theory of "imaginative education" (*The Educated Mind*, 1997), educational development can be conceived as a process or *recapitulation*, during which students' minds are socio-culturally shaped to recapitulate, that is, repeat, the forms of understandings, as these have appeared in our extended cultural history. These forms, also termed socio-cultural cognitive tools of mind, Egan called "Somatic," "Mythic,"

[1]The physicist and philosopher Martin Eger in a series of papers 1992; 1993a; 1993b has skillfully shown how the field of philosophical hermeneutics (the study and interpretation of texts), can be applied to science education when learners seek to find personal meaning and understanding when reading and interpreting textbooks, and participating in classroom dialogue (see also Schulz, 2014b).

[2]Even though "active processing" may be considered something that cannot be encouraged through storytelling, one should bear in mind that storytelling does encourage "active processing," in the sense that the listener is not a passive recipient of information, but one who tries to create meaning by relating new information to prior knowledge. In addition, the listener, in his/her attempt to understand also employ higher order thinking skills, like analysis and synthesis. Who indeed, can doubt the fact that those who listen attentively to a story and try to create meaning do not put the past, the present, and the future in a relationship? This is the power of the story, that many teachers and educators have not really grasped. It is not just about interesting stories that can be used in order to convey important information. It is also about creating meaning through various relationships and associations that the listener constructs (Hadzigeorgiou, 2016).

"Romantic," "Philosophic," and "Ironic," and postulated most cultures moved through these stages as civilizations progressed, although at a diverse pace and performance. Egan's grand theory (or "metatheory") is grounded on the fact of the *historicity* of language in human anthropology and cultural development and how this has managed to shape—albeit in ways not yet entirely understood—both the brain and the mind. "Without the historicity of language, human nature and the human mind remain essentially unchanged in history" (Polito, 2005, p. 486). (See Schulz, 2009, 2014b, for a more indepth discussion).

One can certainly maintain, with little controversy when examining the anthropological record, that there has come to be a general cultural progression of the human race from plain mimicry and artifact construction (common to our primal *homo sapiens* ancestors—"somatic"), to oral language use and society ("mythic"), to creating literacy with the written word ("romantic"), and finally to more complex forms of language symbolism and use, including a shift to theoretical ("philosophic") and even ironic thinking, as noted by others (Donald, 1991). "The exceedingly long historico-cultural development since our early hominid prehistory, which appears to be neither inevitable nor 'progressive' (in the older 19th century evolutionary sense), has nonetheless brought with it the discovery and invention of both *physical* and especially *cognitive* tools, which, according to their own sequence and time, have wrought technological advance as well as expanded the human capacity to reason and make sense of themselves and the world" (Schulz, 2009, p. 262).

Here, however, the focus is strictly on "Romantic Understanding" which is itself a *transitional* kind of understanding, between "Mythic" (i.e., a kind of understanding associated with orality and developed by children in the age range 2–7, who rely on oral language to interact and understand the world), and "Philosophic" (i.e., conceptual or "theoretic" understanding, for those learners in the age range of about 15–20 years). It is important though to point out that Egan's notion of "Romantic Understanding," as a transitional kind of understanding is quite unique (Egan, 1990). The reason is that neither Donald's (1991) distinction between mythic and rational thinking, nor Bruner's (1986) distinction between narrative and paradigmatic (or logico-mathematical) thinking, can explain or account for a transitional stage of understanding (i.e., from mythic *to* narrative understanding *to* more advanced conceptual understanding at the upper grade levels). In other words, Egan's "Romantic Understanding" is a quite distinctive mode of understanding, which is not to be confused or conflated with narrative understanding in general.

Although one could argue that both mythic and romantic understandings are narrative in their nature (i.e., both very young children and teenagers rely on the narrative mode of thinking to make sense of the world and their experiences), these two kinds of understanding represent two distinct ways of making sense of the world. This becomes easily understood if one looks at the specific *characteristics* for these kinds of understanding. For "Romantic Understanding" in particular these characteristics are the following: (a) the humanization of meaning (i.e., students' awareness of the human context of the knowledge and content to be learned); (b) an association with heroes and heroic qualities (i.e., students' association with things or people with heroic qualities, so they gain confidence that they, too, can face and deal with the real world); (c) an attraction to the limits of reality and extremes of experience (i.e., the limits of any new environment and human experience enables students to gain security and confidence in dealing with reality); (d) the experience of a sense of wonder (i.e., astonishment mingled with bewildered curiosity, admiration, and the awareness that one's knowledge is incomplete or erroneous or that some extraordinary phenomenon-exists), and finally, (e) revolt and idealism (i.e., contesting of conventional ideas and all kinds of conventions).

From this general conception of a "Romantic Understanding," an *operational definition* of romantic understanding in the context of school science education can be construed as follows: "A narrative kind of understanding which enables students to become aware of the human context of the subject content that they are supposed to learn, by associating, at the same time, such content with heroic human qualities, with the extremes of reality and experience, with a contesting of conventional ideas, and also by experiencing a sense of wonder" (Hadzigeorgiou et al., 2012, p. 1,112). This definition of "Romantic Understanding," while different from that of conceptual or "theoretic" understanding, is very relevant to school science education in the sense that it relates to the content of many different science subjects. Indeed, the content of science is full of extremes, it can evoke a sense of wonder, and can provide opportunities for associating the subject concepts with people and even things that have "heroic" qualities. It can also provide opportunities for associating the content with the contesting of convention, as in the case of scientists who struggled against conventional and prevailing ideas and beliefs, and dealt with in proper historical context (i.e., Copernicus, Kepler, Galileo, Lavoisier, Priestly, Joule, Young, Darwin, Hutton, Wegener, Tesla, etc.).

It deserves to be pointed out that the humanistic element/context, the heroic element, and the sense of wonder, are similar to the characteristics of "romantic science," which had its roots in the movement of "Romanticism" (as a revolt against many Enlightenment era doctrines), that took place in Europe between 1780 and 1840 (see Poggi and Bossi, 1994; Hadzigeorgiou and Schulz, 2014). Watson (2010) sees the movement as a major contribution to the "second scientific revolution." And even though the term "romantic science" may sound like an oxymoron, even a paradox, given that the prevalent view of science sees its development primarily due to an emphasis on rationalism, deductive thinking, experimentation, reductionism, and the mathematization (modeling) of nature, "there is now widespread recognition of the importance of particular romantic contributions to the natural sciences" (Cunningham and Jardine, 1990, p. 19). This revised historical assessment of "romantic science" can make science teachers and science educators more attentive to Egan's (1997) recapitulation theory, and specifically, to the potential of "Romantic Understanding."

What should be pointed out though is that the development of "Romantic Understanding" of science presupposes that students are given the opportunity to relate the science content *with* the romantic features. Even though students of the age range 7 or 8 to 15 generally understand and relate to the world romantically, that is, by associating reality (e.g., a mountain, a neighborhood, a building, a friendship, a human relationship) with the romantic features, it does not follow that they will understand science romantically. (Quite the contrary, they often find themselves at this age alienated from the content and language as presented in textbooks and classroom dialogue, what Lemke (1990) refers to as the "mystique" of science). Hence, it is vital, if the development of "Romantic Understanding" and ultimately engagement with content knowledge is to be an instructional goal, that students be given opportunities to experience a sense of wonder, to explore the extremes and the limits of reality and human experience, and to associate with heroic qualities, and also to become aware of the human context in which scientific knowledge is discovered and developed. Whether the instructional topic is forces and motion, photosynthesis, electric current, biodiversity, or radioactivity, it should be associated with all the above named features of the mind-set. Perhaps, the best way to associate all the aforementioned features of "Romantic Understanding" with science content is to create a narrative or, better, a story, whose plot incorporates all of them. Such an approach gives students the opportunity to use their narrative mode of thinking and to understand science content "romantically." Egan (1992) had also pointed out that a narrative context for the romantic characteristics "can enhance their power to stimulate and develop the imagination" (p. 72).

One could, of course, very well raise the issue of what empirical evidence exists, as regards the development of "Romantic Understanding." The anecdotal evidence about the educational benefits and perhaps about the effectiveness of romantic understanding are insufficient when it comes to informing instructional and curriculum planning, let alone educational policy. It is true that no empirical study can be found in the literature except the study conducted by Hadzigeorgiou et al. (2012). This study investigated "The Effect of the Nikola Tesla Story" on grade 9 students' understanding of the concept of alternating current. This story, based exclusively on historical events, included all the romantic elements [i.e., the characteristic features of "Romantic Understanding" according to Egan's theory (Egan's, 1997)] and the researchers used a quasi-experimental design (i.e., a two-group, pre-test/intervention/post-test design). This means that the students (ninth graders) who participated in the study were not randomly assigned to two groups. Thus, two classrooms from each of 19 schools (from the wider metropolitan area of a European capital) that participated in the intervention formed the control and the experimental group respectively, with a total of 197 students. More specifically, the intervention was conducted over a period of 10 weeks, with the first 4 weeks spent on the teaching of prerequisite knowledge (i.e., fundamentals of current electricity), the fifth and sixth weeks spent on assessment, while the next 3 weeks were devoted to teaching both groups about alternating current and the idea of the wireless transmission of electrical power. The final assessment of both groups took place during the tenth week. However, 8 weeks later, that is, on the eighteenth week a delayed post-test was also administered to the two groups. The students of the control group were taught about alternating current and the wireless transmission of electricity through direct instruction, and more specifically through the mastery model (see Stefanich and Hadzigeorgiou, 2001), while the experimental group were taught exactly the same content through storytelling (i.e., the Nikola Tesla story)[3].

However, it is important to point out that that study did provide evidence for a significant difference between the control group and the experimental group, in terms of engagement with science content knowledge, retention and understanding. Regardless of the interpretation of significant differences between the two groups (e.g., novelty of the instructional sequence through storytelling, the specific curricular content that was covered, such as current electricity, the Hawthorn effect), the fact that the story helped foster in the students of the experimental group a "Romantic Understanding" of science content knowledge (as all the characteristics of "Romantic Understanding" were identified through content analysis of students' optional journal entries), cannot be disputed.

Certainly more empirical evidence is imperative, but it quite evident that a "Romantic Understanding" of science relates to what the philosopher of science Yehuda Elkana had called "personal science" (as opposed to "public science"). He had argued that the methods of logic are insufficient for describing science as a human endeavor: "logical tools are of limited use in understanding the development of science or, what is even more important, in the teaching of science" (Elkana, 2000, p. 473). Private science, as Hadzigeorgiou and Schulz (2017) argued, is inevitably phenomenological but the prevailing insistence on the "logic" of science, when formulated in public language of "final form science" as found in textbooks, does not give students the picture of science as a human activity, or even a proper historical activity (though the presented history is too often mythical—Allchin, 2013), as pointed out by several previous researchers (see Matthews, 1994, 2015; Hodson, 1998; Donnelly, 2004). A "Romantic Understanding" of science, if it takes place in a narrative learning context, in addition to

[3]There are, no doubt, certain limitations regarding the intervention. As with any quasi-experimental design, the two groups in each school were not similar, even though the students' characteristics, like academic achievement, socio-cultural and economic background, and even their general interests, were considered similar. In addition, the novelty of the intervention for the experimental group students, and not the intervention per se, should also be considered a factor that played a role in the results of the intervention. Moreover, the story itself was quite powerful, not only because it included all the elements. However, the limitations of the intervention should not downplay its effectiveness with regard to student engagement and understanding. The interest, in particular, that was generated by the Tesla story, that is, a story with all the characteristic features that encourage the development of romantic understanding, needs to be seriously considered. Indeed, as Klassen and Froese-Klassen (2014b) have pointed out, "The insights provided by romantic understanding and its success in achieving improved student learning could add an enriching new dimension to the research on interest" (p. 140).

encouraging engagement with science content, gives students the opportunity to understand science as an arduous and exciting, but also error prone, human activity, embedded in a socio/cultural context (Hadzigeorgiou et al., 2012). Moreover, taking a wider view and considering the vocational aspect of school science, a romantic understanding can present science as "a grand adventure," something of vital importance, according to the late Nobel prize physicist Feynman (1964), if we want to attract young students to the world of science and, hence, educate future scientists.

CONCLUDING COMMENTS

This paper discussed the potential of "narrative thinking" and "romantic understanding" to engage students in science, particularly science content ideas and ideas about the nature of science. Even though engagement does not guarantee understanding, the latter always presupposes some degree of emotional and/or cognitive engagement. In light of the fact that both "narrative thinking" and "romantic understanding" are about students' making sense of the world and meaning making, they can both "help us answer two fundamental questions in educational theory: What is significant for students? What is meaningful to them"? (see also Hadzigeorgiou, 1997, 2005b, p. 31; Schulz, 2014a,b; Krevetzakis, 2019). It may very well be argued that the degree to which students become engaged with science, through the opportunities they have to use their narrative mode of thinking and also to understand science "romantically," namely, by being helped to associate science ideas with the characteristic features of "romantic understanding," can show teachers the degree to which students perceive science as something significant and meaningful (Hadzigeorgiou, 2016).

Certainly, the complexity of the processes of both engagement with science and understanding science, one the one hand, and the multiplicity of factors involved in both of them, on the other, makes one cautious about the effectiveness of the use of narratives and stories, and of the "romantic" approach, as was discussed in this paper, to encourage engagement that will, in turn, result in understanding. Putting aside the empirical evidence that exists to date, what should be noted is that what teachers and curriculum designers wish to achieve is to increase the possibilities for students to understand science. Apparently, because of their *inherent* nature, narrative and romantic understanding increase such possibilities (for understanding science). The message from a recent study by Godec et al. (2018) should be a reminder of that. Even though their study—which they approached from a sociological/Bourdieusian perspective—showed that student engagement with science became possible only when students' "habitus" (i.e., set of deeply embedded and internalized dispositions) aligned with the "field" (i.e., the social environment of the classroom with certain sets of rules, relationships, and expectations), they did acknowledge the possibility of broadening the notion of "field," so that more opportunities for more diverse students could be provided.

Thus, in recognizing and valuing the individual capacities of students, teachers could offer more opportunities to more students. Narrative thinking is indeed an individual capacity as is a "romantic understanding" of the world, at least in the case of students approximately in the age range 8–15. In actual fact, such individual capacities are students' "capital," which ought to be considered by teachers and curriculum designers. For it should be noted that it is the "field" that determines whether something (e.g., an individual capacity) can be considered as "capital" (see Godec et al., 2018). Future research is certainly needed to more clearly articulate how such "capital" can be tapped from the various perspectives on teaching and learning science (e.g., sociocultural, conceptual change) so that we better understand and appreciate its potential. But we should be reminded, nonetheless, that this potential has been indirectly hinted at by the educational philosopher Maxine Greene: "the problem in education is how to help students discover the imaginative mode of awareness" (Greene, 1978, p. 186). Both narrative thinking and romantic understanding can facilitate such discovery.

Hence, it is important, in closing this chapter, to point out that more attention should be paid by the science education community to the development of students' *imagination*, by seriously considering the role of the narrative mode of thinking and the development of romantic understanding in the context of school science education. Regardless of the fact that the history of science has provided ample evidence that scientific discovery and scientific understanding are indeed imaginative endeavors (Hadzigeorgiou and Stefanich, 2001; Hadzigeorgiou and Garganourakis, 2010; Hadzigeorgiou, 2016; Lindholm, 2018), in the context of education in general, especially early childhood education, the value of imagination needs to be reclaimed. What the educational theorist Kieran Egan has pointed out should be seriously and carefully considered:

> *A feature of young children's mental life that is commonly asserted as an implication 'of research on their logico-mathematical thinking is that their thought is perception-dominated. If we focus instead on their imaginative lives we can see rather an enormously energetic realm of intellectual activity that is conception-driven.* (Egan, 1999, p. 9).

DATA AVAILABILITY

No datasets were generated or analyzed for this study.

AUTHOR CONTRIBUTIONS

YH is the first author as he had run the original research study in Greece as mentioned in the paper, and whose major research has been concerned with the process of engagement with science content knowledge using imaginative approaches in teaching and learning. However, both have co-authored on several papers together involving engagement and history of science. YH wrote the first draft and RS added substantial aspects (concepts, clarifications, additions, research literature) to the manuscript as it developed. Both authors have read, revised, and contributed to the final version of the submitted paper, and approved the final submission.

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