The Role of Interest in Learning Science through Stories [1]

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Abstract

A major aspect of the power of a historically based science story derives from its ability to cultivate interest in the reader or listener. In this paper, we review the research on interest originating from diverse scholarly areas and apply it to the understanding, construction, and effective use of science stories in both formal and informal learning environments. Significantly, the raising of interest in science addresses the vital concern of declining engagement with school science, which might be thought of as a decline in interest. Prototype stories and methods to incorporate them are included.

Contents

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1 Introduction

For a number of years, now, we have developed the concept, form, and application of the historically based story in science education. Our project seeks to contextualize school science in its humanistic background. We have come to believe that a major aspect of the power of such a story derives from its ability to cultivate interest in the reader or listener. While reading the literature on interest, we encountered the writing of nineteenth-century German philosopher Arthur Schopenhauer in which he conceptualizes interest in the literary arts. He depicts a literary story as

> interesting when it represents events and actions of a kind which necessarily arouse concern or sympathy, like that which we feel in real events involving our own person. The fate of the person represented in them is felt in just the same fashion as our own: we await the development of events with anxiety; we eagerly follow their course; our hearts quicken when the hero is threatened; our pulse falters as the danger reaches its acme, and throbs again when he is suddenly rescued. Until we reach the end of the story we cannot put the book aside … . (Schopenhauer 2006, p. 27)

Our own description of the power of a story resonates with Schopenhauer's seminal description:

> The discovery of a good historically based story is like the discovery of a hidden treasure. Perhaps, the fascination arises from the romance of far-removed events with participants who had the same kinds of hopes, dreams, and struggles as we, and yet, in a very different environment. (Klassen 2006, p. 335)

The reader or listener processes the story both emotionally and cognitively. One way of describing the response is as the raising of interest of a particular kind—what we might refer to as *human interest.*

Schopenhauer's depiction of interest, as engendered by stories, brings to mind our recent empirical study on the effects of a science story as viewed from the standpoint of romantic understanding. From this perspective, the science story contains at least five critical features (called cognitive tools) that include the humanistic element and the heroic, which appear, also, to be a feature of Schopenhauer's conception of story interest. From the perspective of educational psychology literature, however, we were not able to find any literature that deals with the humanistic element directly in the description of interest. The literature deals with text-based interest, but does not specialize in what might, tentatively, be called human interest or story interest. In this paper, we will investigate the various conceptions and findings in the field of interest in order to expand our understanding of the potential effectiveness of the science story and facilitate its more fruitful application both inside and outside the classroom.

The consideration of interest is significant for several reasons. First, it promises to enhance our understanding of how to make a science story effective and of the reasons for its effectiveness. Second, the elaboration of interest will broaden our understanding of the most effective way of utilizing stories in science classes and other science learning environments. Third, an understanding of interest will provide new guidelines for designing learning episodes that can be applied to a broader range of situations. Last, the raising of interest in science addresses the vital concern of declining engagement with school science,[2] which might, just as well, be thought of as a decline in interest.

[2] See, for example, Willms, Friesen, and Milton 2009.

2 Elaboration of Interest as an Influence on Learning

The importance and role of interest was, most famously, advocated and elaborated by Dewey in several of his writings, especially in his *Interest and Effort in Education*. Dewey saw interest as the main motivating factor in learning. Philosopher of education, Mark Jonas, explains that Dewey viewed interest as

> the psychical state that obtains when individuals consider their *self-expression* dependent upon the interaction between themselves and a particular object or idea. … In other words, Dewey believes that students become interested in a particular object (a fact, or concept, or expression, etc.) when they regard that object as so important that if they cannot apprehend it—absorb it, so to speak, through physical or psychical interaction—they will not be able to be the individuals they desire to be. The individual longs to connect his or her *incomplete* being with the being of the object or idea, because the connection fulfills the missing portion of his or her own being. (Jonas 2011, p. 115, italics in original)

Dewey's conception of interest is clearly connected with motivation, and it is interesting to note that he includes physical as well as psychological interactions of the person with the learning environment. His theory of interest, while not exactly the same as the ones put forward today, was, nevertheless, sound and influential, as it was grounded in his philosophy of education and observations of students in his teaching laboratories. Shortly after Dewey's time, the consideration of interest fell into disuse for about 50 years and only saw resurgence in the 1980s with the beginning of the cognitive psychological revolution.[3]

2.1 Definitions of Interest

The concept of interest is rich and diverse, one for which it is challenging to formulate a consensus definition. At the simplest level, the psychological state of interest is closely identified with intrinsic motivation (Schiefele 1991; Silvia 2008). Educational interest arises from an emotional response to certain kinds of stimuli in the learning episode and consists of increased and persistent attention to the interesting situation accompanied by increased cognitive activity and the desire to re-engage. Research has shown that interest is accompanied or, possibly, caused by increased dopamine activity in the brain (Palmer 2009; Willis 2007). Rather than being caused by the environment, interest results from the interaction of the individual with certain specific aspects of the environment. Although many researchers see interest as having both cognitive and affective components (Hidi, Renniger, and Krapp, 2004), Silvia (2008) maintains that interest is an emotion. The two positions are not necessarily contradictory if one sees the emotion of interest as driving cognitive engagement. Most researchers would agree with the summary of Schraw and Lehman (2001) that

> [i]nterest (i.e., liking and willful engagement in a cognitive activity) plays an important part in the learning process, determining in part what we choose to learn, and how well we learn this information (Garner 1992; Alexander and Jetton 1996). Interest manifests itself in several ways, including active engagement, focusing of one's attentional resources, and learning more than one would otherwise learn. Interest affects the use of specific learning strategies and how we allocate our attention (Hidi 1990; Wade, Schraw, Buxton, and Hayes 1993). It also affects our emotional engagement in a task and the extent to which we engage in deeper processing (Schiefele 1996, 1999; Schraw 1998). (Schraw and Lehman 2001, p. 23)

The principal definitions of educational interest have emerged in the context of traditional text-based learning that does not include practical

[3] For a discussion of the changes in Educational Psychology see Klassen (2006).

(or hands-on), social, or humanistic components. Nevertheless, some studies of interest have applied the construct to informal learning environments, such as science centers and other active learning environments, such as inquiry learning and cooperative learning (Renninger 2007; Wellington 1990). The one area which has not seen significant application is that of humanistic learning environments, such as story-based science learning. Given that interest can be applied in diverse educational settings, there is probably no other single factor that can influence learning as significantly as interest, provided that common environmental factors, such as the teacher and classroom climate, are factored out.

2.2 Interest in Science Learning

Most of the research on interest has taken place in psychology and educational psychology with application to text-based learning. In a 1999 study, Kubli surveyed 700 physics students between the ages of 16 and 20 on their attitudes towards various ways of incorporating history in their lessons. Although the focus of the study was not interest, *per se*, it did reveal only a modest interest in history of science. In a 2009 study on interest generated during science-inquiry activities, Palmer observed that, up to that point, very few studies of interest had been carried out in science classes. Studies have often only involved science insofar as they contain science text for studying text-based interest. Although the findings on text-based interest have useful implications for science learning, they need to be extended to include hands-on activities, cooperative learning in science, informal science learning environments, and so on. As has already been mentioned, the application of interest to story-based learning in science has not been developed significantly (see De Young and Monroe 1996).

2.3 Why Should we Embrace Interest as an Essential Aspect of Learning Environments?

Science education has utilized various educational theories, especially constructivism, over the past 30 years, which should have, even with modest expectation, improved student engagement and learning. Yet, we are still facing a crisis of declining student engagement with school science. A recent Canadian study involving over 32,000 students from grades 5 through 12, for example, has revealed the disturbing statistic that only 37% of students are engaged intellectually in their classes (Willms, Friesen, and Milton 2009). The study also reveals that student intellectual engagement declines from 62% in the elementary grades to 30% in the secondary grades. It is obvious that without student intellectual engagement, all our educational efforts in science education are fruitless. Interest assumes major importance on account of its close identification with engagement. Enhancing student interest in school science is synonymous with increasing their intellectual engagement.

In addition to improving engagement and motivation, interest has demonstrably improved learning, *per se*, in several respects. Interesting texts contribute to increased comprehension and learning (Hidi, Renninger, and Krapp 2004), motivate the learner to go beyond the surface of the text to try to comprehend underlying meaning (Krapp 1999), and lead to increased memory, comprehension, and cognitive engagement (Hidi, Renninger, and Krapp 2004). They do so, primarily, by enabling the student to focus attention and process information more rapidly (Hidi, Renninger, and Krapp 2004). Schraw and Lehman (2001) point out that there are no studies that report a negative correlation between story interest and

Table 1 Factors associated with situational interest in the literature

1. Complexity (Silvia 2006)
   a) Obscurity (Silvia 2006)
   b) Mysteriousness (Silvia 2006)
   c) Suspense (Rabkin 1973; Swarat, Ortony, & Revelle 2012)
   d) Anticipation and prediction (Schank 1979; Kíntsch 1980)
   e) Omission of important background information (Tulving, et al. 1965; Bower 1972)
   f) Vividness (Sadoski 2001; Silvia 2006; Schraw, et al. 1995; Vrana et al. 1986)
   g) Intensity (Anderson et al. 1987; Hidi 1990, 2001)
2. Novelty (Sadoski 2001; Berlyne 1960; Silvia 2006; Anderson et al. 1984; 1987)
   a) Surprisingness (Dimulsecu & Dessales 2009; Sadoski 2001; Swarat, et al. 2012)
   b) Variety (Palmer 2009)
   c) Abnormality (Tulving et al. 1965; Bower 1972)
   d) Challenging of beliefs (Frick 1992)
3. Coherence (Sadoski 2001; Silvia 2006)
   a) Narrative mode (Hidi & Anderson 1992; Stein & Glenn 1979)
   b) Story form (Kintsch 1980; Entin & Klare 1985; Hidi & Baird 1986; Hidi 1990)
   c) Plot structure (Bower 1982; Jose & Brewer 1984; Iran-Nejad 1987)
4. Character identification (Anderson et al. 1984; 1987)
5. Comprehensibility (Silvia 2006)
   a) Concreteness (Sadoski, et al. 2000, Wade 1992; Sadoski 2001; Silvia 2006)
   b) Background knowledge (Anderman et al. 2004; Hidi 2001; Hidi & Anderson 1992)
6. Physical activity with a cognitive aspect (Chen & Darst 2001; Mitchell 1993; Palmer 2009)
   a) Hands-on (Swarat, Ortony, & Revelle 2012)
   b) Continuous experiential feedback (Hidi, et al. 2004)
   c) Technological novelty (Sandifer 2003; Swarat, et al. 2012)
   d) Open-endedness (Sandifer 2003)
   e) Choice or autonomy (Anderman et al. 2004; Hidi 2001; Hidi & Anderson 1992; Palmer 2009)
7. Social involvement (Anderman et al. 2004; Hidi 2001; Hidi & Anderson 1992; Palmer 2009)

memory of textual information and that virtually all studies reveal that interest is related to better learning, propositional recall, and holistic text understanding.

Confidence in interest as a central educational construct is enhanced through parallel evidence provided by neurobiological studies of dopamine levels. Dopamine is a chemical neurotransmitter associated with memory and comprehension which facilitates the transmission of information in the brain (Cooper, Bloom, and Roth 1996). Elevated dopamine levels are associated with listening to a story or book being read aloud (Depue and Collins 1999) and with effective learning strategies, such as social collaboration (Rodriquez, Chu, Caron, and Wetsel 2004), autonomy (Roesch, Calu, and Schoenbaum 2007), and hands-on components of learning (Wunderlich, Bell, and Ford 2005). In addition, the primary stimulators of interest—novelty and surprise—also enhance dopamine activity (Alcaro, Huber, and Panksepp 2007). Palmer (2009) explains that dopamine achieves these functions by regulating motivation and producing selective attention or, in other words, by filtering out spurious activity or background noise.

Renninger (2007) brings out the key fact that "interest always results in motivated behaviour" (p. 5). Although we are not claiming that interest is a panacea for problematic areas of science education, its potential for re-focusing the design of educational environments cannot be ignored. In order to address the decline in student interest in school science, for example, refocusing and redesigning the educational approach will be essential. Hidi, Renninger, and Krapp (2004) make the important observation that "such declines are partly due to a lack of environmental support for engaging student interest rather than a developmental shift in the capacity to have interest" (p. 93). The powerful factor in applying the aspect of interest is that its characteristics could potentially have a bearing on virtually every approach used in teaching science—from conventional text-based instruction through story-based learning episodes to hands-on science in inquiry learning approaches.

3 Identification of the Primary Sources of Interest

The literature, beginning in the 1960s, has identified a large number of features that result in student interest (see Table 1 for list of some of them). There has been little effort to segment the features into age-specific categories; indeed, there appears to be little evidence of age-specific dependencies. Similarly, the literature makes very little distinction in interest production by gender, even though a few studies indicate differences; however, these are not pronounced and no systematic patterns are evident. There are various categorization schemes for interest. The consensus scheme breaks interest into situational and individual types, where situational interest depends on the immediate instructional situation and is, therefore, transient. Individual interest reflects a more deep-seated proclivity that an individual brings to the instructional episode. It is likely that repeated exposure to appropriately chosen situational interest stimuli will, eventually, result in the development of individual interest.

In our review of the literature, we have identified a significant number of distinct ways of producing situational interest in learning episodes (see Table 1). We have grouped factors that share common features in categories or groups. Groups 1 - 5 comprise interest factors that all apply to text-based interest. These groups have been arranged in an approximate continuum from complexity to comprehensibility. These categories do not represent various mutually exclusive ways of generating interest but different avenues, any of which can be present. A unique aspect of interest production is that novelty-type features work in tension with comprehensibility-type features. If students, for example, "appraise an event as new and as comprehensible, then they will find it interesting" (Silvia 2008, p. 58). Silvia (2008) explains that complexity or novelty has to be combined with comprehensibility since "[f]inding something understandable is the hinge between interest and confusion" (Silvia 2008, p. 58). The trap in designing for interest, then, is the focusing on originality to the exclusion of familiarity.

3.1 Essential Tensions in Interest-based Learning

Kirschner, Sweller, and Clark (2006) point out that minimally guided, inquiry-based instruction usually results in cognitive overload, confusion, and lack of genuine learning. Their conclusions are consistent with the insight of Silvia that comprehensibility is required in tension with complexity in order to avoid confusion. Silvia's insight raises the possibility of other such tensions. The aspects of open-endedness and choice or autonomy, which are identified as providing interest, must be counterbalanced with appropriate guidance; otherwise, feelings of inadequacy or confusion might result. The aspect of novelty is in tension with familiarity. A certain amount of familiarity is necessary in order to produce comprehensibility. On the other hand, too much familiarity might result in boredom, a phenomenon frequently present in the context of school science and which is on the opposite end of the spectrum from interest. It is important to recognize the tensions inherent in producing interest, as providing appropriate tensions is essential for the design of effective learning environments.

3.2 Seductive Details

Often, one encounters textbooks or other instructional texts that incorporate small amounts of highly entertaining material that relates only distantly to the main point of the text. Such text is incorporated to "spice up" an otherwise dry and uninteresting expository presentation. The thinking is that the interesting and captivating, yet unimportant, information will attract the students' attention just enough for them to remember the surrounding material. A large amount of research on this effect has, however, unequivocally concluded that the inclusion of such details, called "seductive details," actually reduces learning (Garner, Gillingham, and White 1989; Harp and Mayer 1998). The learning decreases because the seductive details confuse the learner as to the intent of the passage and divert the learning focus to an inappropriate context (Harp and Mayer 1998). To be effective, interesting details must align with the main focus of the learning episode or text.

4 A Comparison of Interest and Romantic Understanding

In a recent empirical study, we applied Kieran Egan's notion of romantic understanding in teaching the concepts of AC electricity to grade 9 students (Hadzigeorgiou, Klassen, and Froese Klassen 2012). Romantic understanding, which by definition takes place in a humanistic context, may be defined as the ability to grasp the meaning of the features of subject matter in a manner that tends to be idealistic in expectation and glamorously imaginary, possibly even exotic, and involving the potential for heroic achievement. During the period of their development when they exhibit romantic understanding (approximately between ages 8 and 15), children are attracted, for example, to literary characters who do heroic, but possible, things.

Egan identifies five vital means by which children at this stage make sense of the world and of experience and by which they mediate between the world and the mind. These means, which he calls "cognitive tools," become the specific characteristics of romantic understanding. They are (1) the humanization of meaning, arising from the realization of the humanistic dimension of all knowledge, (2) an association (even identification) with heroes and heroic qualities, (3) a focus on and confrontation of the extremes and limits of reality and experience, (4) a sense of wonder, and (5) the contesting of conventions and conventional ideas.

Hadzigeorgiou et al. (2012), in order to reflect these tools and the instructional strategy in the concept, itself, conceive of romantic understanding as "the motivating insight that emerges through the combined engagement of the emotions and the intellect in response to a specialized text." The instructional strategy of the story is the "specialized text," which specifically incorporates the various cognitive tools. The motivating insight—a combination of the emotions and the intellect—is strikingly similar to the definitions of interest. The identified aspects of interest, as delineated in Table 1, do not isolate the aspect of humanization or a sense of wonder. It is, however, possible to re-interpret the cognitive tools of romantic understanding and designate humanization as the overall context for romantic understanding and the sense of wonder as the interest reaction to the heroic (see interest feature 4), the extremes of reality (see interest feature 2), and the contesting of conventions (see interest feature 2d). In this re-organized

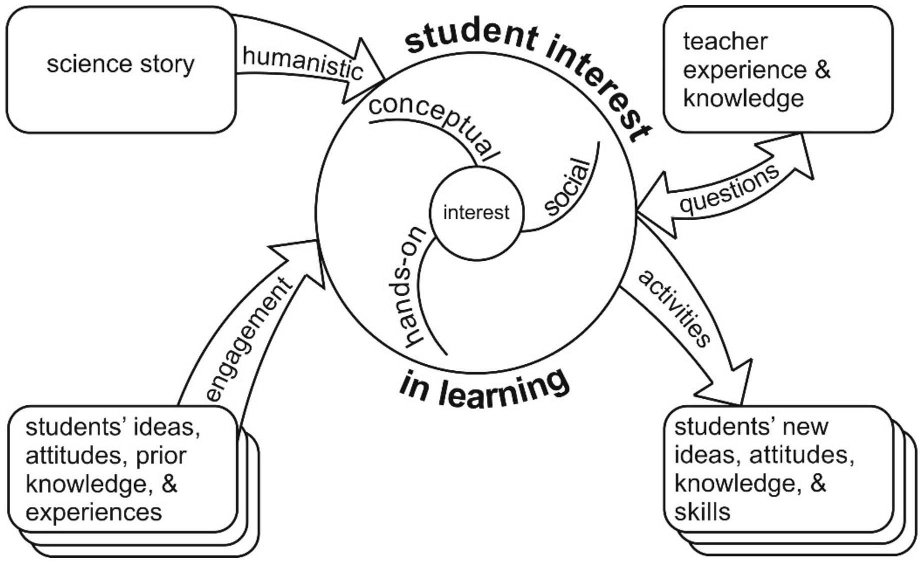

Fig. 1 The story-driven interest approach

sense, romantic understanding seems to coincide with the features of interest. It is remarkable, though, that research on interest has not identified the humanistic context as a catalyst for interest.

A sense of wonder is conceived as "astonishment mingled with bewildered curiosity, admiration, and the awareness that one's knowledge is incomplete or erroneous or that some extraordinary phenomenon exists" (Hadzigeorgiou et al. 2012, p. 1115). Wonder, as an emotional-cognitive complex, appears to be considerably richer in its makeup than interest, which is conceptualized as "liking and willful engagement in a cognitive activity" (Schraw and Lehman 2001, p. 23). 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.

5 Designing Learning Contexts and Episodes for Interest

Categories one through five of the features of interest all relate to the designing and writing of effective stories (Klassen and Froese Klassen 2014). Category 6 relates to hands-on activities and category 7 to social environments. These aspects were included in the story-driven contextual approach (SDCA) of Klassen (2006), which consist of the contexts of the practical (hands-on), social, emotional (story interest), historical (humanistic), and theoretical (conceptual). Of these, the humanistic and conceptual have not been identified in the literature on interest. Not only do many of the elements of interest in Table 1 relate to the story, but they can also be subsumed under the broad category of the humanistic context, making it consistent with the methodology of romantic understanding (Hadzigeorgiou et al. 2012).

We maintain that the design of effective learning contexts and episodes should draw as many of the broad features of interest as is practical. As pointed out above, the SDCA framework of Klassen (2006) takes all of these into account, along with the additional feature of the theoretical (conceptual) aspects of science. Research on interest has consistently revealed that abstract elements do not raise interest as effectively as concrete, hands-on features do. The conceptual aspect of science is, however, central and indispensable to meaningful learning. The key in resolving this apparent dilemma is to tap into the learning benefit of context and the power of story to incorporate seemingly diverse aspects, including the conceptual and theoretical, so that all are necessary. In such a design, the conceptual aspect will not detract from interest. One could, in fact, imagine another tension inherent in interest—that between the practical (or experimental) and the conceptual (or theoretical). Both are necessary but need to be incorporated with consideration to the requirements of interest.

What we have learned from the research findings on interest, romantic understanding, and the story form overlap to a large degree with the SDCA. As a consequence, we have combined our current insights with the original framework to produce a scheme adapted for interest. The revised schema is presented in Fig. 1.

5.1 The Story-Driven Interest Approach

The Story-Driven Interest Approach (SDIA, see Fig. 1) differs from Klassen's original framework in that the emotional context is subsumed by the interest factor and the historical context (from the history of science) is implicitly contained in the science story. The Figure portrays the operation of a contextual learning activity where students bring their ideas, attitudes, and experiences to the learning episode fruitfully, as long as they are intellectually engaged. The motivation needed for intellectual engagement is provided by the interest factors present in the design of the activities and in the science story read by the teacher. The science story supplies a large proportion of the interest by means of storytelling devices, such as suspense, the omission of certain information, the novelty of its account, and the coherence of its structure, which integrates naturally with students' mental structures. Especially important is the portrayal of the character of the scientist in the story, as it may be possible to feature her or him in a heroic light. The story should be designed so as to provide concrete details about the character's actions and situation and the background for the science. The learning activities that accompany the story should feature a hands-on investigation where social interaction of the students is possible. The investigation should raise conceptual questions about the science, posed either by the students or the teacher. When appropriately structured and guided by the teacher, the episode, through its student activities, will result in learning that is represented by new ideas, attitudes, knowledge, and skills. Of particular importance is the integration of the learning with long-term memory.

5.2 The Science Story Structure

According to Klassen and Froese Klassen (2014), a science story contains narrative and other story elements. The following narrative elements serve as a story framework for designing and writing science stories:

1. *Characters.* A main character, taken from history of science, is featured throughout the story and is the primary source of the action.
2. *Actions.* "Someone is doing something." The actions are historically based and accurate or plausible.
3. *Situations*. Narrative has situations or states insofar as the character responds to them or helps to create them.
4. *Consequential Coherence.* Actions and situations are consequentially connected—one necessitates the next, either directly or by implication.

5. *Past Time.* The events take place in the past and are recounted.

A science story includes three additional aspects besides the narrative characteristics:

1. *Plot Structure*. The typical plot structure has six essential elements:
   (a) *Setting the Scene*. An introduction or beginning.
   (b) *A Problematic Situation*. A problem that emerges, usually of a scientific nature or necessitating the involvement of science.
   (c) *A Crisis*. Something has to be done by the main character because of the problem at hand.
   (d) *A Critical Decision*. The main character makes a crucial choice.
   (e) *The Climax*. The story reaches a turning point when events change rapidly for the better or worse.
   (f) *The Conclusion*. The problematic situation is resolved in either a positive or negative way.
2. *Agency.* The outcome of the story hinges on a critical choice or choices made by the main character.
3. *Science and NOS Content.* Depending on the purpose, the science story will contain either or both science and nature of science (NOS) content. Such content should be embedded from the perspective of the character(s) and appear to be natural and necessary to the development of the story.

5.3 An Example of an SDIA Learning Sequence

A topic that is frequently revisited in science and physics curricula is that of the pendulum. The following hypothetical learning episode is loosely based on instructional designs at the authors' institution. The learning episode begins with a story of Galileo and the pendulum. As a student in Pisa, Galileo attends mass at the cathedral. Not being able to maintain his attention on what the archbishop is saying, he begins to daydream about the nature of motion and reflects on his skepticism of the Aristotelian view being promulgated by his professors. His somewhat glazed eyes come to rest on the massive, gently swinging, bronze lamp hanging from the ceiling high above. Over the next few minutes, he notices that although the swing is dying out almost completely, it still seems to be oscillating with the same frequency. It occurs to him that the regular back and forth motion of the chandelier is inconsistent with Aristotle's law of natural motion. The story goes on to portray aspects of Galileo's recurring experiments with pendulums, his conclusions, and his refutation of Aristotelian physics. Near the end of his life, Galileo goes blind and cannot conduct experiments anymore, but, with the assistance of his son, he continues his work in physics. At that point, he has one of his most important insights: the pendulum can be incorporated into clocks to regulate the motion and greatly improve their accuracy. He describes the mechanism to his son, who makes a diagram of it. Sadly, Galileo dies before seeing his great idea become a reality. Shortly after Galileo's death, Christian Huygens originates almost the identical idea and publishes it, denying posthumous priority to Galileo. The story includes details of the various mathematical relations in Galileo's theory of the pendulum that involve its period, length, weight, and size of swing, all of which he measured in order to justify his mathematical (geometrical) relations.

Normally, the reading of the story is followed immediately by the students recording the questions that they have at that point. Depending on the time available, these questions can be discussed by the whole class and clarified and summarized by the teacher on the whiteboard, for future reference. The purpose is to have some of the answers emerge during the activities that follow. The students then form groups of two or three, and the teacher describes hands-on investigations of the properties of the pendulum. The novel and challenging aspect of the investigations is that the students, like Galileo, have no accurate timekeeping device for measuring the period of the pendulum and no meter stick. All they have at their disposal is a quantity of string, scissors, a selection of bobs of different known weights, a protractor, and an appropriate stand for suspending a pendulum. Some students are asked to investigate the dependence of period on size of swing, others, the dependence of period on mass; and others, the dependence of period on length. It is remarkable how resourceful students are in inventing a unit and method of determining length and a method of measuring time. Some will use heart rate; others, a rhythmic song; and still others (the most successful ones) will use a "standard" pendulum as the unit of time. After a suitable length of time (30 - 45 minutes), the students prepare to present their results verbally to the class (about 10 minutes of preparation). Each group has about seven minutes to make its presentation and give its conclusions. Depending on the size of the class, it is possible to complete the entire process in about three hours. If the activity needs to be spread over two periods, the dividing point should be after the summarizing and recording of questions. A follow-up to the student presentations is a revisiting of their questions to see which ones have been answered. A follow-up homework assignment might consist of researching answers to any remaining questions for discussion in the following class. If the teacher so desires, a pencil-and-paper test may be given in approximately a week's time to check for long-term memory and learning.

The design of the SDIA will have drawn on many of the features of interest, including the story form and its plot structure, the identification with Galileo's heroic qualities, the novelty of the story and the investigation method, concreteness, anticipation and prediction, hands-on activity, open-endedness, autonomy, and social interaction.

6 Interest in Informal Learning Environments

Informal learning has particular value in improving student attitudes towards science, making them aware of various phenomena in nature and providing them with physical manipulation skills (Wellington 1990). Student attitudes engendered in informal science learning environments—field trips, exposure to digital media, museum tours, and science center visits—stand in stark contrast to those commonly exhibited towards school science. Solomon (2005), for example, found that five- to ten-year-old children were eager to discuss science at home, but when their parents directed the conversation to their experiences with science in school, the children became tense and did not wish to continue the conversation. The effect of out-of-school learning should not be minimized. Fadigan and Hammrich (2004) go so far as to suggest that students who continue studies in science in school are those who have had early experiences with out-of-school science learning.

The interest-producing potential of science centers, which are our focus, is far-reaching. An examination of Table 1 in the context of science center exhibits and experiences reveals that they can demonstrate anticipation and prediction, vividness, surprisingness, variety, abnormality, concreteness, hands-on experience, continuous experiential feedback, technological novelty, open-endedness, choice or autonomy, and social involvement. The issue amidst all of the potential is whether appropriate tensions, for example, between complexity and comprehensibility, novelty and background knowledge, or autonomy and guidance exist. Without these tensions, the experience may result in cognitive overload and create confusion (Kirschner, Sweller, and Clark 2006; Silvia 2008). A mitigating factor for science centers is that the concepts being portrayed generally focus on the existence and experiencing of scientific phenomena without consideration of cause or theory, reducing the cognitive resources required of the students.

6.1 An Untapped Resource for Science Centers: The Science Story

The current status of development and research on the science story has refined the genre to the degree that it is possible to design and write brief, yet effective, stories that could be utilized even in science centers. In the case of the science center, the usual approach is to use little or no textual information in the exhibits. In order to bring focus on the science concept and its humanistic context to the related exhibit, science stories could be told by center staff. As already mentioned, the telling of stories generally results in elevated dopamine levels on the part of the listener (Depue and Collins 1999), which suggests that the story fits well with the objective of generating interest. Additionally, as shown by Hadzigeorgiou et al. (2012), an appropriately designed told story can generate all the conceptual learning that could be produced in a conventional science lesson.

6.2 An Example of a Science Story Suitable for Museum or Science Center Use

In electricity exhibitions, artefacts can impart considerable interest due to the sparks they generate. One such case is the electrophorus, which involves Volta in its invention. The story, inserted below, is provided as an example of a story which could be incorporated into an exhibit. The presentation could either be verbal or textual with illustrations.

Electricity without Limits

Eighteen-year-old Alessandro Volta was passionate about electricity, indeed so passionate that he announced to his somewhat startled family, "I'm not going to university! I would rather spend my time in investigating electrical phenomena." Alessandro's family was used to his surprising turns. As a child, Alessandro had not learned to speak until he was age four, which had alarmed his parents, but then little Alessandro suddenly began to develop at a furious pace, out-performing all his school mates. In his father's words, "We had a jewel in the house and did not know it!" And so, at age eighteen, the gifted Volta launched into a scientific career by beginning to write to the leading scientists of the day about his ideas, and, surprisingly, they replied.

By the age of 24, Volta had written his first book on a theory of electricity. To Volta's disappointment, he found that his theory was not generally accepted and did not serve to enhance his scientific reputation. He continued to struggle with his theory for some time. That year, Volta's associate, Paolo Frisi, gave him some good advice. He advised Volta to put as much emphasis on scientific instruments as on theory and then placed a newly translated copy of the famous Joseph Priestley's history of electricity into Volta's hands. It was Priestley, one of the leading scientists, who had responded to Volta and encouraged him to pursue electrical experimentation. Volta must have taken Priestley's and Frisi's advice to heart because from then on his work took a turn towards invention. But what would that do for the success of his career?

Volta was fascinated with the idea of inventing a portable and endless supply of electricity. Up to that point, scientists had built only large electrical machines on the principle of one material rubbing over another and generating sparks. Volta used a different approach. Could he use an electrically charged material somehow to push charge into a conductor instead of having it rub off? He set out to produce the ultimate charge-producing material by having his assistant, Polonio, heat a mixture of turpentine, resin, and wax, which they poured into a shallow, metal pan to cool. They called it the "cake." They fashioned a cover for the cake out of a piece of wood with rounded edges overlaid with tin foil. To the top of the cover they attached a glass insulating handle. Volta called his new device the "perpetual electrophorus." Would it produce an electrical charge in the cover?

The big moment had arrived. Volta began the procedure by touching the cover. Then he lifted the cover by its insulating handle. He brought his other hand near the cover and jerked back involuntarily as a spark jumped from the cover to his hand. "That's a good start." he exclaimed, "But is there more?" Volta replaced the cover again, touched it, and lifted it. Another spark! "Fantastic!" Volta shouted. "Now I should be able produce any amount of charge." Polonio was looking on. "How does it work?" he asked. Volta frowned, "That's too complicated a question to discuss right now."

The electrophorus quickly gained fame for Volta throughout Europe, not the least of the reasons being that Volta wrote many letters describing the device to important scientists and sent many models as gifts to influential people. The electrophorus, however, was not without controversy or mystery. Some said that its seemingly endless supply of charge daunted the most celebrated scientists of electricity in Germany and Italy. In London in a presentation on the electrophorus before the Royal Society, a local scientist lamented that "It is hard to say how or where the electricity is deposited; there is so much of it." Benjamin Franklin, on the other hand, when hearing about the device, immediately recognized it as a type of Leyden jar. Eventually, everyone came to understand how the electrophorus worked.

Although the electrophorus launched Volta to fame, it did not serve as the endless source of electricity for which he had been looking. Later in his life, he accomplished this feat by a much greater invention—that of the electrical battery. Volta's prominence had brought him to the attention of Emperor Napoleon of France who met with Volta to discuss his electrical inventions. Napoleon had become a great admirer of Volta. Two years after their meeting, while on an official visit to the National Library, Napoleon noticed a memorial on the wall dedicated to the famous French writer Voltaire, with the inscription "The Great Voltaire". Impulsively, Napoleon struck out the last three letters so that it read "The Great Volta."

Volta must have been very glad that he followed the wise advice of Priestley and Frisi to become an inventor of electrical devices.

7 Discussion and Further Work

It is evident that the research findings on interest can have a bearing on improving the effectiveness of science learning, especially if they are combined with what we already know about the closely related fields of humanistic science-learning environments, romantic understanding, contextual learning, and the science story. It is noteworthy that the humanistic element was not identified in the literature among the features which generate interest. In view of the recent research on romantic understanding, which identifies the humanistic element as being central to science learning through science stories, further investigation is necessary to ascertain the optimal relationship between interest and the humanistic element, especially insofar that the two can be integrated in learning environments.

Of particular significance is the insight that the elements of interest must exist in tension with elements of the commonplace, so that complexity must be in tension with simplicity, novelty with familiarity, autonomy with guidance, and social interaction with independence. The realization that interest cannot be applied indiscriminately but must be combined with certain other critical elements and considerations is vital to its successful implementation.

Our investigation of interest in science supports our proposal that the primary vehicles for its development are the science story, hands-on activities, and social interaction, provided that these elements are combined in a contextual structure and that due attention is paid to counterbalancing the raw elements of interest with the elements of the commonplace.

We cannot have any illusions about the effort required to develop the potential that interest offers. If, for example, science stories are to be incorporated successfully into formal and informal learning environments, the theory of science-story writing will need to be promoted and developed among the stakeholders. It will also be essential for science scholars, museum curators, science-center directors, educators, and writers to collaborate in the undertaking of producing science stories of appropriate length, featuring notable scientists who made scientific contributions that are of interest to the general public and to those who are involved in school science curriculum development and delivery. Such initiative will require the recruitment of writers in the humanities who are willing to redirect their efforts into the sciences. Without a concerted effort in this area, a valuable learning tool will be in jeopardy of being relegated to research, by interested scholars, in non-applied settings.

As a next step, we recommend a collaborative pilot study on stories in science centers or museums. Either or both a told story and a text-based story could be used. The determination of interest in such a setting can be made relatively uncomplicated by measuring the holding time of the exhibit for each visitor as compared to other exhibits and conducting representative exit interviews. The story of Volta serves as a prototype.

The research on interest has raised significant findings in regard to its impact on student learning. Of special importance is its potential to improve motivation, engagement, and learning in science in a variety of settings. This aspect is particularly vital in view of the alarming decline of student interest in school science, especially in the middle years. Hidi, Renninger, and Krapp (2004) point out that this trend is already evident in early years as children experience disappointment at being prevented, by the system, from pursuing topics that they find motivating in a way that they find fulfilling. Moreover, it is most significant that "such declines are partially due to a lack of environmental support for engaging student interest rather than a developmental shift in the capacity to have interest" (Hidi, Renninger, and Krapp, 2004, p. 93). We must conclude, therefore, that developing learning environments and episodes in a manner that raises interest in an appropriate manner will have a fundamental and positive effect on student intellectual engagement with science.

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