Storytelling as a Strategy for Understanding Concepts of Electricity and Electromagnetism

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ABSTRACT: In our research we tried to investigate if students will develop inquiry and especially proper skills for designing experimental activities in order to explore hypotheses, to interpret, and in general to comprehend new knowledge (metacognitive skills), as the impact of storytelling strategy during teaching and secondly if they will exploit, the knowledge and the skills, they have developed in the process of teaching and learning, for the explanation of every day life phenomena or applications of science. In order to achieve the above objectives we carried out on the one hand, a bibliographical research in which we established the certainty that modern thought is integrated in dialogical and narrative forms. In addition the conceptual approach, which places emphasis on the purely cognitive dimension of the process of knowledge and ignores inspiration or imagination, is ineffective. This necessitates to the turn to other approaches to teaching and learning (one of these is storytelling), which cultivate the imagination and inspiration and make science learning attractive to students. On the other hand, in order to confirm our findings we conducted a research in five sixth grade primary school classes about the effectiveness of storytelling in teaching science to these students. The findings of this research are described in our paper and seemed to be encouraging.

KEYWORDS: storytelling strategy, science teaching, research, primary school.

1. Introduction

Some of the characteristics of the sciences are their rational character, the extended—after Galileo Galilei—use of mathematics, the recourse to predictions, even of statistic character, the formalization, the high complexity and the acceptance of corollaries only after exhaustive argumentation. For these reasons modern science cannot reach an ultimate phase; neither is in position to formulate an exhaustive binding ontology, as it is happening in the case of Aristotelian *"science"*. But the cognitive quest of man cannot reconcile with the *"principle of economy of thought";* since the acceptance of a position is established on its ontological profundity, its rational and reflective substantiation and not obligatorily on its austerity or the brevity of its steps. Especially, nowadays the request of ontological and reflective establishment of knowledge becomes a necessity, in the context of a cultural integration which shall evolve in history (Kokkotas, 2009).

Furthermore, reflection does not accept the viewpoint that knowledge and culture can reach a final accomplishment. The mundane character of this approach supplies cognition with social, dialogical and narrative elements. It is essential that contemporary thinkers should accept the consideration that modern thought is integrated in a dialogical form, in order to perform the request of knowledge (Plakitsi & Kokkotas, 2003). The scientific research has ceased to proceed in one person's expressions. Actually narrative, according to Ricœur (2004), has dialogical character and according to Kristeva (1969) this is evident even in the case of monological thought. Wittgenstein (1978) formulates in the *"Tractatus Logico-philosophicus"* that *"the subject is the limit of the world"*. Furthermore, Genette (1969) argues that it is impossible to write a text in exclusively one person form. The potential character of modern science causes the inertia of the distinction between teaching and learning (someone teaches and some others learn) and attributes to education an active and elicitational character.

We believe that the link between science and Science Education needs to be re-determination and revision of their relation since a potential interaction has been developed between them. Additionally, this revision is reinforced from the research findings for the ineffectiveness of conceptual approach which placed an emphasis on the purely cognitive dimension of the process of knowledge but ignores inspiration or imagination (Hadzigeorgiou, 2002). It also stems from the fact that we all know that school science lacks the vitality of investigation, discovery, and creative invention that often accompanies science-in-the-making.

For the improvement of this situation the abandoning of the academic tradition in the primary and secondary science education is proposed, and at the same time its connection with the human element (AAAS, 1990, UNESCO, 2000). In this context the exploitation of History of Science could have a vital role in Science Education.

Some writers argue that the humanizing and clarifying influence of History of Science brings the science to life and enables the student to construct relationships that would have been impossible to be perceived in the traditional way science was being taught (Cohen, 1950/1993; Jung, 1994; Kipnis, 1996; Koul & Dana, 1997).

We agree with Kyle's opinion (Kyle,1997) *"…students ought to experience the how of scientific enquiry, rather than merely being exposed to what is known about science"*. Our interpretation of the *"how of scientific enquiry"* includes the intellectual struggles among scientists within the historical context.

Through such a teaching approach students would probably appreciate science as a value-laden procedure where objectivity, curiosity, pursuit of truth, intellectual honesty, humility and commitment to human welfare are central (Stevenson & Byerly, 2000). The students are helped to perceive that scientific knowledge is not as objective as it is presented in science textbooks, since it is the outcome of a human endeavor full of successes but also of failures. If we accept that knowledge is indeed a human construction or an appropriation then not only the prior conceptions of the learner but also his / her sentimentalities such as fears, anxieties, hopes and expectations should be taken into account in the teaching process.

We can support the view that storytelling could be regarded as a proper strategy which has the potential to contribute to the humanizing of teaching, to the improvement of the climate in science classrooms and to the development of positive attitudes towards science learning. In this context the understanding of science concepts is improved.

2. Storytelling and Stories in Science Education

The importance of storytelling in teaching is stressed by some educators as follows: *"We learn from stories. More important, we come to understand – ourselves, others, and even the subjects we teach and learn. Stories engage us. … Stories can help us to understand by making the abstract concrete and accessible. What is only dimly perceived at the level of principle may become vivid and powerful in the concrete. Further, stories motivate us. Even that which, we understand at the abstract level, may not move us to action, whereas a story often does"* (Noddings & Witherell, 1991: 279-280).

In our view any science teacher irrespectively of the level he/she teaches has the experience that telling a story in the science classroom is a powerful tool for engaging students, which means that telling a coherent story may be the best way for learning, remembering and re-telling of ideas of science (Ellis, 2000). Nevertheless, science teaching with the use of stories is not an easy process, and according to Egan it is quite complex and difficult to convey their meaning in a condensed fashion (Egan, 1979, 1986, 1992, 1997, 2005). This is true since it is necessary for the teacher to create an affective environment and engage his/her students in discourse. Of course it depends on the ability of teachers and students to infuse the narrative with color and interest in order to make it attractive and meaningful. Teachers, experienced in using this approach in primary and secondary schools, prefer to work with units stretching over a semester or more, incorporating many elements of the curriculum in the students' research, discussions, role playing, artwork, and other learning activities.

Furthermore nowadays, storytelling has appeared as an acceptable form of research and construction of knowledge. It is regarded as one of the most appropriate pedagogical approaches for teaching and learning of science in all levels of education (Bruner, 1994; Connelly & Clandinin, 1990; Denison, 1996; Dyson & Genishi, 1994; Eisner, 1997; Fairbanks, 1996; Klassen, 2006; Nikitina, 2003; Oliver, 1998; Polkinghorne, 1995; Sparkes, 1995, 1999, 2002; Stinner, 1994, 1995; Stinner et al., 2003; Witherell & Noddings, 1991).

Given that stories facilitate understanding, cause engagement, and produce motivation, and even help us to understand ourselves, the appropriate use of the story form in science teaching can, indeed, become an heuristic teaching device that is not only attractive, but also self-sustaining (Klassen, 2006). Furthermore, stories constitute a natural and effective way of thinking and can be used as a means of communication and cultural expression (Manna & Minichiello, 2005).

Narratives are constructed through the story schema which is defined as "*a mental structure consisting of sets of expectations about the way in which stories proceed*" and as reflection (Mandler, 1984: 18). Narrative thinking involves matching a problem, situation, or an idea to the story schema. It is a heuristic process, *"one which requires skill, judgement, and experience"* (Robinson & Hawpe, 1986: 111).

The transformation of the educational material in the form of story in order to be not only attractive, but also educative, is needed more than a simple sequence of historical events. The beginning of the story is crucial and decisive for provoking the imagination of students and exciting their admiration (Hadzigeorgiou, 2006). Thus, it is needed to include a general background about the main structure of the story. In the main part of the story the concepts, which have to be taught, should be interrelated in a clear structure. At the end of the story it is interesting to be included a review and an ethical message (e.g. an important idea) for the learners. The narrative form of the presentation of the concepts aims not only to create perspectives, hopes, motivations and wonder to the students, but also to facilitate their deeper understanding and remembering.

We believe that History of Science could be an important resource from which we can get appropriate material for composing stories in Science Education, because it links concepts, theories, phenomena and events of science with the scientists who lived, worked and affected from the specific sociocultural environment of their era. But, it should be realized that the place of history is neither to make a conceptual point only, nor just to place entertaining vignettes in the text but also to introduce the humanistic element and aspects of the nature of science into the process of learning science (Klassen, 2006). However, we emphasize that the story should be chosen in a manner that shows respect to the originators scientists and portrays them in a fair and balanced way.

The objective of accuracy or faithfulness to the historical record must, in turn, be balanced against the demands of a curriculum that limits the depth to which the story can be probed. For example, portraying scientists as human beings and giving students the opportunity to become effectively involved in the story of science are worthy goals in themselves (Klassen, 2006; Stinner et al., 2003).

In order to achieve an effective incorporation of aspects of History of Science in science teaching, we have to make rules how to choose the proper resources which should be characterized for their validity and credibility and the proper material which should be in accordance with the aims of the specific teaching approach.

3. Storytelling and the Understanding of Science Concepts

How does storytelling help the understanding of science concepts? This question is important for Science Education, because the understanding of science concepts is a basic theme of it.

We believe that storytelling helps the development of romantic understanding because makes students experience curiosity, mystery and even wonder. Some writers argue that romantic understanding is an alternative to conceptual understanding, on the following grounds a) it represents a different way of making sense of the world and human experience, through an attraction to their exotic, strange and mysterious features and desire to transcend everyday reality, b) it gives the idea that knowledge is a human construction, and cannot even be considered outside of the context of its construction c) it makes use of the students' imagination and d) it has an aesthetic dimension (Egan, 1990; Hadzigeorgiou, 2005). Thus, romantic understanding could result to the development of inspiration which has a cognitive and an emotional dimension. Although feeling and thinking go hand in hand, emphasis on the cognitive dimension of the learning process has resulted in the neglect of emotions, despite the evidence for the importance of the latter (Goleman, 1995; Ortony, Glore & Collins, 1989). Inspiration can also lead students to some kind of action. This action may refer to further reading and further thinking or even the development of a special interest for science or a particular topic.

Storytelling also develops the students' anticipation. Dewey (1934: 55) talked about anticipation and argued that consummation *"does not wait in consciousness for the whole undertaking to be finished. It is anticipated throughout and is recurrently savoured with special intensity".* Therefore students should be provided with ample opportunities to experience anticipation and this can be added to the experience of mystery and wonder that a good story usually creates, so the anticipation can help the development of romantic understanding. Teachers can use narratives into which the scientific ideas are embedded (Hadzigeorgiou & Stefanich, 2001; Stinner, 1995) and which provide students with opportunities for *"reconnecting the knowledge with the transcendent qualities of the individuals who produced it"* (Egan, 1990: 139). Anticipation can also experience if the students can study the life of the great scientists and dramatize important events of their lives.

Storytelling as an art of speech can facilitate the development of students' imagination since *"The development of imagination is linked to the development of speech, to the development of child's social interaction with those around him, to the basic of the collective social activity of the child's consciousness"* (Vygotsky, 1987: 346). So, by extension storytelling helps the development of romantic understanding since imagination is one of its characteristics. According to Vygotsky (1998) *"imagination is...a function which is linked to emotional life, the life of drives and attitudes, is linked to intellectual life ...everything that requires artistic transformation of reality, everything that is connected with interpretation and construction of something new, requires the indispensable participation of imagination".*

In our opinion, imagination as the basis of all creative activity is an important component of absolutely all aspects of cultural life, enabling artistic, scientific and technical creation alike. In this sense, *"everything around us that was created by the hand of man, the entire world of human imagination and creation is based on this imagination"* (Vygotsky, 2003: 9-10), viz. Vygotsky considered the development of imagination as necessary for the technical, scientific creativity of children as it is for arts. The arts and sciences both demand the need for the cultivation of imagination in our school curriculum (Gajdamaschko, 2005). Vygotsky proposed the development of imagination through the mechanism of acquisition of cultural tools in the curriculum that could become the content of the children's' imaginative activities.

According to Vygotsky another important ability which is developed concurrently with imagination is the ability to transfer the function from one object into other. This ability is very closely connected to the development of symbolic function in a child which means that the development of imagination could help the development of abstract thought (Vygotsky, 1978: 103) and also in the understanding the abstract concepts in science. Although, it is argued that this imagination *"…does not develop all at once, but very slowly and gradually evolves from more elementary and simpler forms into complex ones"* (Vygotsky, 2003: 12).

From the above, it is deduced that storytelling develops: the inspiration, the anticipation, the imagination and the romantic understanding. If we accept that romantic understanding not only paves the way for conceptual understanding, since it inspires students, but it can also be a prerequisite for such an understanding, we strongly argue that storytelling is an important pedagogical strategy which can contribute to the development of both conceptual and romantic understanding.

4. Research Design and Methodology

Although, there are a few studies that actually investigate the impact of storytelling strategy on learning in the classroom, we could indicatively relate some studies that contribute to the argumentation of this impact:

- Applebee (1978) and Favat (1977) examined children' reactions to folk stories and found that they made connections between the plots and events in books by connecting their own life experiences to that of fictional characters.

- Well (1986) investigated the links between storytelling and school success and found that the key to literacy development was consistent exposure to storytelling and narrative discourse.
- Current studies underpin Well's findings, suggesting that storytelling from culturally diverse sources supports the creation of multicultural awareness in classrooms (McCabe, 1997) and encourages the development of health self-concepts (Paley, 1990).
- Egan (1999) found that the classic fairy tales have considerable power to engage the imagination of young children in classrooms.
- Traditional literatures from a wide variety of cultural contexts have also been found useful in the growth of imagination (Rosenblaut, 1976; Gallas, 1994) morality (Coles, 1989; Zipes, 1997) and self-identity (Chinen, 1996).
- Mello (2001) researched how the art of storytelling contributes to the development of students, i.e. to think critically and deeply about social issues, explored their own lives through the lens of story. Storytelling provided a model for students to create relationships between themselves and the teacher/researcher.

The objectives of our research were to examine:

- If students will develop inquiry and especially appropriate skills for designing experimental activities in order to explore hypotheses, to interpret, and in general to comprehend new knowledge (metacognitive skills), as the impact of storytelling strategy during teaching (design - comprehension of knowledge).
- If students will exploit, the knowledge and the skills, they have developed in the process of teaching and learning, as the impact of storytelling strategy, for the explanation of every day life phenomena or applications of science (application - extension of knowledge).

Our study was designed with these objectives, assumptions and questions in mind. So, we decided to develop a project which incorporated historical aspects i.e. an authentic story about Oersted's experiments and a story based on real events (May on 1676) adapted from a letter sent to a scientific magazine of London. Four worksheets were designed for the needs of the research in an attempt to transform the already discussed theoretical framework into *"hands on and minds on activities"* for the students of the sample. The project (teaching intervention) was implemented in five classes each of which had approximately 20, sixth grade primary school, students. All classes were from the broader area of Athens, Greece for the minimization of confounding variables interference and originated approximately from the same sociocultural environment. The duration of the teaching for each class was twelve hours in total, implemented in a month (a worksheet once a week).

Table 1: The schools participated in the implementation of the project

Serial Number	**School of Implementation**	**Classes**	**Number of Students**
1	3rd Primary School of Kallithea, Attiki, Greece	2	(20+19) 39 sixth Grade students
2	6th Primary School of Galatsi, Attiki, Greece	2	(21+21) 42 sixth Grade students
3	1st Primary School of Paiania, Attiki, Greece	1	19 sixth Grade students

After the implementation of our project we expect the students of the sample to be able to:

- identify ways science is used responsibly in the community,
- identify the information needed to make decisions about an application of science,
- identify factors that influence perceptions of people about science,
- analyze costs and benefits of alternative scientific choices about a community problem,
- analyze the influence certain scientists have had on the ways we think about the world, and
- analyze the interactions between scientific developments and the beliefs and values of society etc.

In order to develop the above skills the teachers (during the implementation) focused on specific issues by asking students questions to redirect their thinking (e.g. *'How..?'*, '*Why…?'*, *'What if…?'* etc.). In particular, primary school students through appropriately designed activities were given opportunities to:

(a) consider the importance of evidence and creative thought in the development of scientific theories;
(b) consider how scientific knowledge and understanding needs to be supported by empirical evidence;

(c) relate social and historical contexts to scientific ideas by studying how at least one scientific idea has changed over time.

We exploited storytelling as an essential teaching strategy in order to engage students in active participation by teamwork, collaboration, argumentation, problem-solving and practical work approaches.

The implementation of the project was videotaped and it was encouraging that students while participating in the project were excited with the activities, the practical work and the stories that they listened to. Teamwork also was revealed to be satisfactory for many students, especially when an experiment was to be designed and conducted by the team. Stories and questions were presented to students, responses recorded, and then questions, as well as analytical perspectives, were reworked and reinterpreted, depended on student feedback. The goal of the study was to get the most holistic information possible from our sample so as to include participants in the exploration and development of the research (qualitative and quantitative research). Data indicates that combining storytelling with post-performance discussions enhanced students' ability to clarify and examine their own biases, and misconceptions (qualitative and quantitative data).

Care was taken to capture a legitimate understanding of the context of the research by presenting a picture as complete as possible of what participants actually said, did, wrote down, created and perceived. Thus, in order to have a broaden picture of the results and the impacts of the storytelling strategy we decided, apart from the qualitative data analysis, to design a quantitative data analysis too. Validity and credibility issues (Maxwell, 1996; Mello, 2001) were deliberately structured into the research design and plan including: a) using methodology that corresponds to the design with qualitative approaches; b) including on-going collaborative approaches to discussion and investigation of research questions; c) paying attention to disconfirming and divergent data; d) collecting multiple data from multiple sources as a way of checking out of researcher beliefs, assumptions and biases.

4.1. The Teaching Intervention

Our teaching intervention (project implementation) was designed in such a way so that we could check the impact of storytelling on the understanding of scientific concepts and phenomena of electricity and electromagnetism. It is necessary to mention that the teaching means, the experimental and the inquiry methodologies, the teaching approaches, which we adopted were the same in all classes of our sample. This was achieved because the five teachers, who had to implement the project in their classrooms, had an in-service training by the researchers. So, in our research the only variable (dependant) was the storytelling. Especially, each teacher told the authentic story of Oersted to his / her students, who accidentally observed that, when a conductor with electric current was brought very near to a magnetic needle, then the needle deviated from its original equilibrium position. After that students were asked a) to design an experimental arrangement using the materials they had on their desks, having no guidance from their teacher and b) to observe what Oersted had observed some hundred years ago.

In addition, students were asked to explain the deviation of the magnetic needle. Their classified answers appear in Table 3 below. These are the views of students at the beginning of the implementation of our project. The students, in order to change their views and construct the new knowledge, were asked to implement a new experimental arrangement including the magnetic needle and a magnet (Table 4). The purpose of the research was students to ascertain the behavior of the magnetic needle, when they bring close to it a magnet. Furthermore, they were asked to compare the behavior of the magnetic needle (or the compass in other similar activities) in both cases namely in the first case when they brought the conductor carrying electric current and in the second when they brought a magnet. Students' answers about the behavior of the magnetic needle, when it is brought into the magnetic field of an electric current, appear in Table 3 below.

Table 2: The teaching module of the project

Serial number	**Title of the lesson**	**Duration**
1	Experimentation with magnets	3 hours
2	Electric current, compasses and magnets	3 hours
3	The story of Oersted discovery	3 hours
4	The story of Thunders and Compasses	3 hours

Through the experience students got from the above two lessons they were asked to explain an unknown phenomenon to them, which is included in a real and attractive story (based on real events adapted from a letter sent to a scientific magazine of London, May on 1676). The story refers to the surprise of the captain of a ship in a voyage to Barbados when he realized that all the compasses of it lost their orientation, when a thunder fell very close to the ship. Each teacher had to tell the story in a storytelling way to his/her class and to ask students to explain the phenomenon (the strange effect of thunder upon the magnetic compasses of the ship). Students had the opportunity to read the story and to explain the relation of the thunder with the electric current of Oersted's experiment (application of knowledge to life). Students' classified answers appear in Table 4 below.

4.2. Data Analysis

We have already mentioned above, in the research design and methodology, that we will present qualitative and quantitative data in order to have a broader and more holistic picture of the results of our study.

From the videotaped data processing we observed that almost all the students of the sample, after they have listened to the original story of Oersted's experiment (authentic text from the History of Science), designed a similar experimental arrangement in their classrooms with considerable convenience and without needing the guidance of their teacher. Furthermore, from the analysis of the recorded discourses of the students of the sample (during they were working in their teams) we ascertained that the storytelling experience was both educative and powerful because it offered them an opportunity to check their understanding through a negotiation between them.

All the qualitative data presented below is quoted verbatim. No part of the transcribed text has been adjusted or changed to make it easier to read. However, this data has been pre-selected as indicative of the larger data set.

So, we think that it worth mentioning that although students had to face a more complicated experimental arrangement than that of Oersted (they had to include a switch in their electric circuits), they didn't ask for their teacher's guidance. We will report some discourses among students while they were trying to implement the experimental arrangement spontaneously.

Discourse 1

Manos (a student who acts as the representative of his team): Madamme, come here to see. We have made it! We hold the cable close to the magnetic needle (he shows how he brings near to the magnetic needle, the cable) and we switch on. Then, we observe the deviation of the magnetic needle.

Nicos: …to repeat it …to check the behavior of the magnetic needle?
Ann: When we bring the cable with current above the magnetic needle, it loses its (equilibrium) position.
Manos: It's fun. When we switch on the magnetic needle loses its position, and when we switch off the magnetic needle returns to its (initial) position.

<u>Discourse 2</u>
George: …to bring the current near the magnetic needle.
Antonio: I believe that the battery (he means, of the electric circuit) should be near the magnetic needle.
Mary: The battery?
George: No, I insist that the cable must be near…
Antonio: OK! Switch on…
Mary: If we switch on, nothing will happen.
George: Don't you remember that last year we have learned that when we switch on, the electric current flows in the circuit? Let us try!
Antonio: Well, I think that something it is wrong. I don't see the movement of the magnetic needle.
George: Pay attention, when we bring the cable of the electric circuit (the electric circuit is close) near the magnetic needle, then it loses its position and you can observe its movement.
Antonio and Mary (simultaneously): Ah!!! I can see it; I can see the movement of the magnetic needle.

Furthermore, we include indicatively the following discourse because on the one hand it shows that students enjoy the procedure by making clear that their learning is their own responsibility and on the other hand they develop skills like: formulating hypothesis, making predictions, inquiring through practical work with real materials and by designing experimental arrangements or by wondering: *"What will happen to the magnetic needle if we switch off?*", *"What will happen to the magnetic needle if we reverse the cables at the two terminals of the battery?"* etc.

<u>Discourse 3 (First Part)</u>
Stelios: I believe that the magnetic needle loses its orientation, because the electric circuit which is very close affects it.
Helen: I believe that the battery and the switch contain some magnetic properties and this is the reason of the movement of the magnetic needle.

Georges: I think that when we switch on then an electric current flows in the circuit, which affects the magnetic needle, as, if it was also banded to the electric circuit.
Stelios: But you can see that the magnetic needle is not banded to the electric circuit.
Georges: Yes, it is not banded to the electric circuit, but when we switch on, then electric charges flow through the cables, I believe that these have magnetic properties, which affect the magnetic needle and it loses its equilibrium position.
Kosmas: Yeah, I also believe, that the magnetic needle is affected by the electricity and, so it does not balance any more pointing at the some direction as previously.

Apart from the above qualitative data we continue with the quantitative data concerning the classified in six categories answers of the students of our sample, to the question of the worksheet: *"How do you explain the deviation of the magnetic needle, when the conductor in which flows the electric current, is very close to the magnetic needle?"* (Table 3).

Table 3: Answers (%) of the students of the sample to the question: "How do you explain the deviation of the magnetic needle when a conductor with electric current is very close to the magnetic needle?"

Categories of answers	**Percentage (%)**
No answer	4
Answers on the basis of the description of the material used	14
Answers on the basis of the description of the phenomenon	20
Answers based on the relation between magnetism and electricity	22
Answers based on the explanation of the electric current	28
Answers based on the explanation using the scientific model (the electric current which flows through the conductor acts as a magnet on the magnetic needle)	12

As we can see from the above Table 3, a satisfactory percentage (22%) of the students believe that there is some relation between electricity and magnetism, which they do not describe. It is also interesting that a significant percentage (28%) of them give in their answers explanatory views supporting that the deviation of the magnetic needle is due to the electric current. In this way they identify a cause of the deviation of the magnetic needle and they express a causal reasoning in their answers, which is very important. Only 12% of the students manage to give complete scientific answers, using the scientific model, whereas, the majority of them (14% and 20% equal 34%) give simple answers, without any attempt for explaining the phenomenon.

Students' indicative answers which can be classified in the above categories (Table 3) are the following: a) 1st category *"no answer",* b) 2nd category *"the battery, the cables, the switch constitute an electric circuit, which is near to the magnetic needle",* c) 3rd category *"when the conductor with the electric current is near to the magnetic needle, then it deviates from its equilibrium position",* d) 4th category *"there is some relation between electricity and magnetism",* e) 5th category *"the magnetic needle deviates because the conductor has electric current"* and f) 6th category *"when electric current flows in a conductor it behaves like a magnet and attracts the magnetic needle"*. Similar answers to the above have been given by the students of the sample to the rest of the questions presented in Tables 5 and 6. Their answers have been classified in the same categories respectively.

In Table 4 we present students' answers on the question: *"How do you explain the deviation of the magnetic needle, when we bring close to it a magnet?".*

Table 4: Answers (%) of the students of the sample to the question: "How do you explain the deviation of the magnetic needle, when we bring close to it a magnet?"

Categories of answers	**Percentage (%)**
No answer	3
Description of the phenomenon	17
Explanations based on the scientific model(e.g. the magnet attracts the magnetic needle)	80

As Table 4 indicates a small percentage of the students (3%) did not give any answer to the above question, whereas 17% of them simply described what they observed, namely the phenomenon. As we can see from Table 4, students, after having implemented the experimental activities on the interactions between the magnet and the magnetic needle, have given the explanation (80%) that the phenomenon is due to the fact that the magnet attracts the magnetic needle, which is in accordance with the scientific model. This high percentage of scientific answers for the properties of the magnet shows that students have comprehended this phenomenon, and it will act as scaffold to understand the relation between electricity and magnetism.

Students' indicative answers which can be classified in the above categories (Table 4) are the following: a) 1st category *"no answer",* b) 2nd category *"the magnet comes close to the magnetic needle and it deviates from its equilibrium position",* c) 3rd category *"the magnetic needle deviates from its equilibrium position because the magnet attracts it"*.

We underline that we designed experiments for students with magnets and magnetic needles because they have got experience and previews knowledge of their interactions, so that it could be easier for them to think analogically in order to explain the behavior of the magnetic needle when it is brought into the magnetic field of an electric current.

It is obvious from the following discourse (which is the succession of the 3rd Discourse) that after the experimentation with magnets, students manage to give complete explanations about the deviation of the magnetic needle, when a conductor with electric current is brought near to it.

<u>Discourse 3 (Second Part)</u>

Helen: I wonder, on what will we finally agree?

Stelios: We all agree that the electric current, which flows through the cables, affects the magnetic needle and the compass and they behave as, if a magnet was near to them, but there is not a magnet on our table. So? Well, I believe that the electric circuit behaves like a magnet, when we switch on and thus the magnetic needle does not balance in the same direction. Also when we reverse the connection of the cables at the poles of the battery, then the magnetic needle and the compass turn the other way round. Also when we switch off, then the magnetic needle and the compass take their original positions, but it does not happen immediately.

In Table 5 below we present the answers of students to the following question of the worksheet: *"How do you explain the deviation of the magnetic needle, when a conductor with electric current is brought near to it?".*

Table 5: Answers (%) of the students of the sample to the question: "How do you explain the deviation of the magnetic needle, when we bring close to it a conductor with electric current?"

Categories of answers	Percentage (%)
No answer	0
Answers on the basis of the description of the material used	0
Answers on the basis of the description of the phenomenon	7
Answers based on the relation between magnetism and electricity	13
Answers based on the explanation of the electric current	33
Answers based on the explanation using the scientific model (the electric current which flows through the conductor acts as a magnet on the magnetic needle)	47

As we can see from the above Table 5 a satisfactory percentage (47%) of the students answered correctly this question. If we compare the percentages of this category of answers in Tables 3 and 5 we can conclude that the answers which are in accordance with the scientific model have a considerable increase of 33%. This can be attributed to the properly designed and implemented experimental activities, carried out by the students in their teams.

It should be mentioned that from the comparison of the initial views of students and the ones after the teaching intervention from Tables 3 and 5 and especially for the category where the students explain the phenomenon with the presence of the electric current there is no significant change between the percentages of the initial views and those after the teaching interventions (28% at the beginning, 33% after) whereas, there is an important change in the percentages before and after the teaching intervention, in the respective categories where students described the phenomenon in Tables 3 and 5 (20% at the beginning, 7% after).

We underline that the majority of the students of the sample, after the teaching intervention, explained the phenomenon and concluded that a) the electric current was the cause for the movement of the magnetic needle and b) there must be a relation between magnetism and electricity. Furthermore, they agreed that the electric current behaves like a magnet and attracts the magnetic needle. For example the students of a class, allocated in five groups gave the following answers per group, after they have implemented the

Oersted's experiment. They observed the movement of the magnetic needle when they switched on and off and then they expressed their opinions classified as follows:

- *1st Group of students' answers:* We believe that the electric current affects the magnetic needle. So, the electric current is the reason for the movement of the magnetic needle.
- *2nd Group of students' answers:* Because there is electric current in the cables of the circuit (the electric circuit is closed) the magnetic needle loses its equilibrium position.
- *3rd Group of students' answers:* The magnetic needle loses its equilibrium position because of the electric current.
- *4th Group of students' answers:* We believe that there must be a relation between magnetism and electricity and this relation is the cause for the movement of the magnetic needle.
- *5th Group of students' answers:* We believe that the electric current attracts the magnetic needle. When the electric circuit is closed, the electric current that flows is like a magnet and attracts the magnetic needle.

Furthermore, we found interesting to include the following discourse because it is obvious that the students of the sample participated actively and with a high degree of interest due to the storytelling strategy. In our opinion, the story of the Oersted experiment helps learners to make connections to what they already know in order to contextualize what is unknown and enables them to control their understanding and expand their knowledge.

Discourse 4

Dimitris: When we bring a magnet near to a magnetic needle then it loses its position, it happens almost immediately. The same will happen when we bring it near to an electric circuit. Again the magnetic needle swings around and loses its position that it had before, but it does not happen immediately *(Comments of the researcher: The student hints that the magnetic field of the magnet is stronger than the one created by the electric current which flows in the circuit.)*

Antonis: So? What do you believe that will happen to the magnetic needle, if we connect two or three batteries in the electric circuit? Well, I think that the electric circuit will behave as a magnet but much stronger than we have with one battery.

Renton: Let us try and see what will happen. Really, Dimitris is right. Now the needle is swinging quickly.

Antonis: Let us reverse the cables at the two terminals of the battery and observe if the magnetic needle swings at the opposite direction compared with its previous swinging
Dimitris: Yes! I believe that it will swing at the opposite direction, as it happens with the magnet. When we bring the north magnetic pole of a magnet near the south 'geographical pole' of the magnetic needle *(Comments of the researcher: Obviously the students confuses the south pole of the magnetic needle with the south geographical pole of Earth.)* then there is an attraction between them, whereas when we bring the south magnetic pole of the magnet near the south pole of the magnetic needle then there is a repulsion between them.
Osman: Look, really the magnetic needle swings at the opposite direction in relation to its swinging before. But let us repeat the experiment …we have to be sure. Please, reverse again the cables at the terminal of the battery, wait for a while for the magnetic needle to balance its direction (of equilibrium) and switch on. Yeah…

In Table 6 we present the answers of students to the following question of the worksheet: "How do you explain the fact that after the thunder the compass of the ship lost its orientation and didn't indicate the north direction?".

Table 6: Answers (%) of the students of the sample to the question: "How do you explain the fact that after the thunder the compass of the ship lost its orientation and didn't indicate the north direction?"

Categories of answers	**Percentage (%)**
No answer	0
Answers on the basis of the description of the material used	0
Answers on the basis of the description of the phenomenon	3
Answers based on the relation between magnetism and electricity	6
Answers based on the explanation of the electric current	16
Answers based on the explanation using the scientific model (the thunder acts as a magnet on the compass)	75

As we can see from Table 6 students explain in a percentage of 16% the phenomenon of thunder using the analogy of the electric current finding a causal relation. But in this case students' answers which express a complete scientific view (the thunder affects the behavior of the magnetic needle of the compass as if it was a magnet) reached the 75%. The comparison of these two percentages with the respective one from Table 5 (47%) has a specific interest, since there is a significant increase in the construction of the scientific model from the learners which can be attributed to the contribution of storytelling. Although, students had experimented in their teams about the behavior of the magnetic needle, the compass, the magnets and the conductor with electric current, nevertheless the percentages, of the construction of the scientific model (47%) lower compare with the one (75%) which appeared after the storytelling. The impact of this strategy on the one hand motivates the students and on the other contributes to the comprehension on the scientific knowledge.

Finally, a story based on real events described in a letter (May on 1676) and sent to a scientific magazine in London, was adapted and told to the students of the sample. We will report indicatively, three discourses among students who were working in teams, in order to show their views or beliefs about their first attempts of interpretation of the phenomenon which is described in the story.

Discourse 5

John: The thunder has inside a magnet which attracts the magnetic needle of the compass.

Mary (1): Well, the thunder is similar to a battery. As the battery has a few volts and could move the magnetic needle of the compass from its equilibrium position, the thunder has millions of volts and could similarly move it.

George: Thus, the thunder attracts the magnetic needle as a magnet.

Discourse 6

Ann: Hmm! The thunder is electric current and this current behaves as a magnet.

Bill: Yeah! I agree with you.

Mary (2): I agree, because there is nothing else around which could attract the magnetic needle of the compass except the thunder.

Discourse 7

Dimitris: The thunder has electric current which affects the magnetic needle of the compass.

Catherine: Can I add something else? I will tell you my opinion. I believe that the thunder has electric current which attracts the magnetic needle of the compass and acts like a magnet.

5. Discussion

We have attempted to testify the assumption that storytelling strategy can provide an educative environment that help students of our sample develop individual perspectives. This strategy could be considered as a powerful and effective tool to teach science concepts in primary school students because it motivates them by involving them emotionally, so that they could develop romantic understanding, stimulate their imagination, their inspiration and lead them to the conceptual understanding. Additionally, we believe that this strategy can serve to reduce the teacher - student distance by making the classroom climate less formal and more personal.

Storytelling along with the content of stories from History of Science have an impact on students' thinking, explanation, experimentation, learning, understanding and in general fulfilling the pedagogical aims and objectives of the current science curricula. Furthermore, the storytelling engages students to critically thinking and analyzing evidence and finally developing positive attitudes towards science and its offering to human culture.

Specifically, we found out that an appropriate science story involves the listener in many of the following procedures: gathering the facts of the story, making predictions about the outcome, and checking their hypotheses against the unfolding details of the story. Science process skills are some of the means that scientists employ to study e.g. the story of the universe. By asking good questions, formulating a hypothesis, designing an investigation, collecting data, analyzing and reordering data and drawing conclusions, a student as a "young scientist" is engaged in scientific inquiry.

Also, we employed stories in the worksheets to make abstract concepts personal and tangible and convey important facts within a dynamic context so the facts stick, they have more meaning and impact. Thus, we achieved one of our purposes which was to transform the classroom (a primary school classroom specifically) into *"a forum for scientific discourse"* so that students can function as novice researchers by extending their knowledge from the already known to the unknown and in this way they interpreted applications of science in every day life. As Jackson (1995) points out and we implemented in this study *"stories do not simply contain knowledge, they are themselves the knowledge we want students to possess"* (p.5).

Thus, storytelling provides an organizing structure, not only attractive and effective but also self-sustaining, for related knowledge and experience in science classrooms because it can motivate and facilitate teaching and learning of science concepts.

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APPENDIX

Some indicative science stories used in the research after appropriate elaboration in order to be incorporated to the students' worksheets

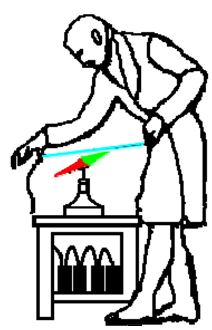
THUNDERS AND COMPASSES

Adapted from a letter send to a scientific magazine of London:
Dublin, May the 10th, 1676

Sir,

This 'gmujfig' narrative, concerning the strange effect of thunder upon a magnetic compass; I have from one Mr. Howard that was master of several ships, and a man of good credit.

He tells me, that being once master of a ship in a voyage to Barbados, in company of another, commanded by one Crofton of new England, they were, in the latitude of Bermuda, suddenly alarmed with a terrible clap of thunder, which broke this Crofton's fore-mast. By the time the noise, together with the danger of this frightful accident, was past, Mr. Howard, to whom this thunder had been more favorable, was however no less surprised, to see his companion's ship steer directly homeward again. At first he thought that perhaps the confusion, that the late mischance had put them in, might have made them mistake their course, and that they soon perceive their error. But seeing them persist in it, and being by this time almost out of call, he tacked and stood after them; and as soon as he got near enough to be well understood, asked where they were going. But their answer and by the sequel of their discourse, it at last appeared that Mr. Crofton did indeed steer by the right point of his compass, but that the needle was turned round, the North and South points having changed positions. Upon examination he found every compass on the ship in the same state. This strange and sudden accident he could impute to nothing else but the operation of the lightning or thunder newly mentioned. He adds, that he lent Crofton one of his compasses to finish the voyage; and that those thunder struck ones did never to his knowledge recover their right position again.



Source: Philosophical Transactions, vol. 27, 1676

In 1776 and 1777 the Bavarian Academy of Sciences had even offered a prize for the best essay on the question: Is there a physical analogy between electrical and magnetic force?

In 1805, just after Oersted's contact with Ritter in Jena, experiments involving the earth's magnetic properties were carried out. Hachette and Desormes attempted to determine whether swinging an electric pile within the interior of the earth produced any detectable effect.

Finally, Oersted himself proposed in 1808 that a prize be offered for an answer to the question: What is the relation between electricity and magnetism? There is no record, however, that anything came of it.

Gregory, F.: *Episodes in Romantic Science, Oersted and the Discovery of Electromagnetism,*
http://www.clas.ufl.edu/users/fgregory/oersted.htm