DEPARTMENT OF EDUCATION AND SPECIAL EDUCATION

USING STORYTELLING TO CONVEY SCIENCE AMONG DEAF PUPILS IN GREECE

A class intervention on learning the concepts of heat and thermal conductivity of materials

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Abstract

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Purpose: The following study focused on whether deaf pupils perceive the concepts of heat and conductivity differently, and in particular more scientifically, before and after a new teaching method that uses storytelling and problem-based learning techniques. It also aimed to determine whether the teaching method has an impact on pupils' motivation, on the growth of academic knowledge and on the appropriate scientific understanding of physical concepts. It took place in three primary education deaf schools in Greece.

Theory: The project is based on Conceptual Change theory. This theory is part of a social constructivist paradigm that is pupil-centered and focuses on children's own ideas about natural phenomena. Central to the theory is the claim that pupils' learning occurs through cognitive conflicts which lead to alteration of their previous misconceptions with new ideas that are closer to the scientific way of thinking

Methods: The study is action research, involving practical, researcher-guided interventions in science teaching, undertaken by teachers participating in the research. Data was collected during various research activities and analyzed using qualitative methods. The two main data collection methods used were interviews with the teachers, and pre- and post- study questionnaires administered to the pupils. The languages that were used in the schools are Greek and Greek sign language, so that all research findings are translated into English.

Results: Storytelling is found to help deaf children better understand abstract scientific concepts such as heat and conductivity. Storytelling is also found to have a positive impact on deaf pupils' motivation to learn natural sciences.

List of Abbreviations

D/HH……..Deaf and Hard of Hearing
GSL…….....Greek Sign Language
SCM……..…Social Constructivist Model
CCT……..…Conceptual Change Theory

List of Definitions

Heat	Heat is defined as the amount of energy transferred from one body to another. Heat always flows from higher temperature bodies to lower temperature bodies. (Greek textbook for physics in 6th grade, 2006)
Thermal energy	The energy of a system corresponding to a state of particle agitation is referred to as a form of internal energy of that system-sometimes called thermal energy. (Erickson & Tiberghien, 1985) The thermal energy of a body is the kinetic energy of its molecules due to their continuous and random movements. (Greek textbook for physics in 6th grade, 2006)
Thermal Conduct	The process of the transfer of energy (Erickson & Tiberghien, 1985) When heat is transmitted by conduct, the body molecules located in higher temperature regions transmit heat to adjacent molecules located in lower temperature regions. (Greek textbook for physics in 6th grade, 2006)
Conductor/insulator	The transmission of heat through one material body is called transfer by conduct. Depending on how easily the heat is transmitted to a material, this material is qualified as a good or bad heat conductor. (Greek textbook for physics in 6th grade, 2006) A good heat conductor is a material that allows fast heat transfer. Insulators are the bodies that prevent the transmission of heat. (Greek textbook for physics in 6th grade, 2006)
Concept	Concepts are to be understood as basic units of knowledge that can be accumulated, gradually refined and combined to form ever richer cognitive structures" (Sfard, 1998, p. 5 as cited in Leach & Scott (2008).
Conceptual ecology	In the year 1972, Stephen Toulmin introduces the idea of "conceptual ecology" in his attempt to understand the nature of knowledge. Specifically, he saw the structure and the development of knowledge in terms of a metaphor in the field of ecology. According to this metaphor, people live in a "spiritual" environment, which includes the cultural beliefs of the people living there: the language and theories that its people support about how the world functions etc. This environment promotes the development of specific ideas and it prohibits the development of other ideas. The term "conceptual ecology" refers to the dynamic interaction between the cognitive structures of a person and the "spiritual" environment that he inhabits. (Hewson & Hewson, 1984). According to Toulmin (1972), the concepts are categorized in specific conceptual frameworks, which people use in order to predict and explain facts. One such conceptual framework, for example Newtonian mechanics, is a conceptual adjustment in the world of scientific knowledge. In different historical and cultural "ecologies", different concepts and different conceptual

	frameworks are possible to develop in order to explain same phenomena. [1]
Cognitive conflicts	"A phase of dissatisfaction with the existing concepts, where the pupils should realize they need to "reorganize", "restructure" or change to some extent their existing ideas or concepts." (Limón, 2001)
Motivation	"Energy or drive that moves people to do something by nature. It is a theoretical concept created to provide causation in human behavior" (Han & Yin, 2016)
Narrative	"A form of communication involving a temporal sequence of events influenced by the actions of specific characters." (Dahlstrom & Ho, 2012)
Deaf Culture	Each of us has several cultural identities. Our beliefs and values, from our family, influence the manner in which we respond to our surrounding. Deaf individuals bring these beliefs and values with them. These ideas are then shared and modified to represent the culture of the Deaf community. Within this culture, there is folklore, history, song, poetry and art, Sheetz (2004: 19 as cited in Naidoo, 2008)
deaf	Audiologists use the term 'deaf' to identify individuals who have varying degrees of hearing loss. Educators also use this term to label those whose hearing loss necessitates the provision of special services, Sheetz (2004: 17 as cited in Naidoo, 2008)
Deaf	The term 'Deaf' with a capital 'D' has been used to identify those who have some degree of hearing loss, who identify with and behave like other 'Deaf' people, and who share the same cultural values of the Deaf ethnic group, Sheetz (2004:18 as cited in Naidoo, 2008). The term "Hearing-Impaired" is considered offensive by some Deaf people, as it overlooks the importance of Deaf culture and sign language.

1 For more on "conceptual ecology" look at: Toulmin (1972), (Hewson &Hewson, 1984), Posner *et al*. (1982), Scrike &Posner (1985, 1992), Ju Park (2006)

List of Appendices

Preface

This master thesis exceeds the 30,000 words limit that the program guidelines suggest. This is because the research was designed as an action research spread out across three participating schools. A teaching method and learning task were developed and implemented, multiple data collection instruments were used for collecting data, and much of the analysis has involved rich description and active interpretation. In order to assemble optimal meaning from the results, factors needed to be taken into consideration that influenced the teaching interventions, such as the physical and psychological environments of the schools, the teachers' ideologies and motivation, and the teaching processes. The research is based on Conceptual Change Theory. It is a broad theory that helps situate and interpret the results in depth, but this necessitated a detailed introduction of it. All these parameters are, for me, vital to the quality of meaning making of the results. Reporting all this added substantially to the word limit: altogether, a much larger than usual program of research was carried out. In good consultation with my supervisor, I decided to sacrifice the word limit rather than sacrifice the quality of the work. I ask for your understanding in considering the substantial size: I am aware what I ask of my readers, who are of course free to read selectively.

Konstantina Kemou

Introduction

The natural sciences, the sciences dealing with the study of the natural world, are a scientific field that covers a large volume of knowledge. Natural science knowledge ranges from theoretical, law-based models of the universe to the decoding of the genetic material which is the basis of human existence. This knowledge also extends to interpreting phenomena that occur and that we see in our everyday life. This scientific field, due to the broad knowledge it includes, has concerned many educators worldwide, about whether it should be taught, and more specifically if it can be taught in elementary schools. A first argument in the question of whether natural sciences should be taught in primary education is that they are an important part of the pupils' lives, as they study issues from the natural world that are an important part of global cultural knowledge (Halkia, 2008). Natural science provides us with the tools not only to find answers for the inherent internal questions that each person has for the world around us, but also to understand our existence and our position on Earth and in the Universe.

Since natural science teaching is thereby rendered important, further questions should be asked about its conduct in the school environment. What criteria should be used for the selection of the thematic units that are to be taught at school; and what goals and methods should we use, so that pupils can be gradually introduced into the way of thinking and the procedures of the natural sciences? It is obvious that such questions create many further thoughts on how scientific knowledge might be adapted to the particular context of the school, the age of pupils, and the mental capacities of each one of them, considering of course also pupils' interests, their emotional needs, and the sociocultural environment that the pupils came from. Thus, from the late 1950s and following Paul Hurd's book "Science Literacy: Its meaning for American schools", the integration of natural sciences in schools and the pursuit of scientifically educated children began to be discussed. By the end of the 20th century, most European countries had revised their national curricula for the teaching of natural sciences. The curricula gradually introduced greater focus on the scientific education of pupils, initially in secondary and then in primary education. In Greece, at the end of the 19th century, experimental physics and chemistry had been introduced as subjects of compulsory education at the schools' curriculum. These original programs were designed assuming a vertical transfer of knowledge and were hence nothing more than a list of physics' concepts that pupils had to memorize, without caring whether or not real insight from learning was achieved (Halkia, 2008). With the passage of time and mounting foreign influence on Greek curricula, more analytical programs developed that focused on the pupil and his/her learning of natural sciences, and that through procedures of inquiry, experiments and observation mimic the research process itself.

However, the situation in special education does not show the same development as in general education. In Greek special education, the teaching of natural sciences is based on a curriculum designed according to traditional principles of perception (Kakos, 2010), which is applied to all the other junior high special schools and special high schools in the country. (Παιδαγωγικό Ινστιτουτο, 2004). As a result, the concept of "heat" for example, a concept not only abstract and difficult in its teaching approach but also important, can be found in different conceptual contexts in many different ways, often treating it as an abstract and mathematical concept that the pupil has to comprehend through methods of teaching which are full of ambiguities and phenomenological generalizations (Kakos, 2010).

According to the former president of the Department of Special Education of the Pedagogical Institute, Venetta Lampropoulou as translated to English from Greek, "in Greece, despite the fact that special education has operated in an organized way for more than 25 years, there have not yet been developed appropriate analytical programs that correspond to all the pupils' special needs. This results in the unsuccessful attempt to implement a general special education curriculum. These conditions call into question the effectiveness of the special education provided in our country". Lampropoulou's conclusion emphasizes the need for the development of analytical programs, teaching approaches and tools that are suitable to special education (ΥΠΕΠΘ-Π.Ι. Department of Special Education, Curriculum for Special Education, page 2-7, Τμήμα Ειδικής Αγωγής, Χαρτογράφηση – Αναλυτικά Προγράμματα Ειδικής Αγωγής, σελ. 2-7).

Part of special education are the Greek deaf schools that follow the special education programs for D/HH (deaf and hard-of-hearing) pupils. Many practices from special education are embedded in the

curriculum for the D/HH as Deaf education is one of the many parts of special education. Therefore, when we discuss Deaf education, we discuss a part of the special education curriculum that is adjusted for people with hearing loss. Mackintosh *et al*. (1994), although science is deemed important, it seems not prioritized in teaching and in curricula. The emphasis (both on a practical level and an academic level) is on the linguistic and cultural perspectives and less on the scientific and conceptual change teaching when it comes to teaching D/HH pupils. The state of the special needs curriculum in Greece, and the particular written and oral language demands present in Deaf education, indicate the need to create a new teaching plan that focuses on learning science, and at the same time include the linguistic and cultural needs of D/HH pupils. There are various teaching practices in science teaching for D/HH pupils. However, in this study we will focus on implementing CCT which can be beneficial for the D/HH pupils. The teaching plan introduced via this study is based on storytelling and problem-based techniques. It specifically focuses on the area of heat and thermal conduct, one of the most abstract concepts in science teaching in the early stage of learning about natural science. The teaching plan follows the characteristics of the "learning in science"2 perspective. It was implemented in three deaf schools in Greece, over a period of 8 weeks.

This thesis is divided in two main parts: 1. The theory and 2. The research. The theoretical part, is divided in three chapters. In the first chapter, the characteristics of Conceptual Change Theory (CCT) are presented together with the ideas from the Social Constructivist Model (SCM) and how these ideas influence the didactic tools that were used in the teaching. In the second chapter, the alternative ideas (that is, ideas at variance with a natural scientific concept that are often of pupils' own making) of the pupils about heat and conductivity are presented. Their ideas are presented in two subsections; one subsection is referring to the alternative ideas about the concept of heat and the other subsection about the concept of thermal conductivity of the materials. The third chapter is a review of the current and most influential literature in the field.

The research part includes three more chapters. In the first one, I describe the methodological procedures and choices, the methods, the sample and the research tools. In the second chapter, the findings from the three schools are presented and analyzed together with the theory and answers to the research questions are provided. In the final chapter, a critical discussion is conducted in order to attribute meaning to the data collected and compare them with the already existing literature. The final conclusions are assembled, and suggestions are made for future research.

2 For more information on the learning in science perspective see Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Auckland: Heinemann.

Part one | Theoretical framework

Chapter 1: The didactics of physics

1.1 General

Conceptual Change Theory was chosen as most suitable theoretical framework for this research. The theory will be situated within the more general context of Individual and Social Constructivism, as described in Driver *et al*. (1994) and Leach & Scott (2002 and 2003). Educational science articles are introduced that combine findings from research on both individual and social perspectives, describing also how scientific knowledge is constructed. Researchers have used many elements from various sociocultural perspectives, all contributing to a general theory of individual constructivism in education, enriching it with new pedagogical dimensions. They created, in this way, a new educational science model of social constructivism (mediated learning), which incorporates elements from both individual constructivism and sociocultural perspectives in educational science. What follows is an introduction to CCT, as set within such a social constructivist understanding of mediated learning.

1.2 The social constructivist model

Drawing upon a combination of cognitive, individualistic and social approaches, CCT is based on the theoretical and empirical insights from three main exemplary strands of scientific inquiry: a) the pedagogical theory of J. Piaget of how the child constructs knowledge during his interaction with the physical world; b) the pedagogical studies from D. Ausubel (1968) which propose that the conceptual evolution of the pupil is dependent on the background knowledge that the pupils have in a specific area; and c) the perceptions of science philosophers, such as T. Kuhn (1962), who discussed that the construction of scientific knowledge is achieved through a series of conflicts with the "daily" way of interpreting phenomena, and S. Toulmin (1972), who argued that the "conceptual ecology" of pupil determines which concepts will be accepted and which will be declined (Anderson, 2007).

According to the individual constructivism paradigm within the educational sciences, pupils already possess specific ideas and perceptions about the physical world and how it functions, which they have constructed from interaction with the physical world (Piaget, 1951). However, due to the fact that individual constructivist ideas were focusing on the individual and ignored the social dimension of knowledge construction, conceptualizations of scientific learning started in addition to draw from sociocultural ideas proposed by different researchers. Most important among them, according to Anderson (2007) the theoretical studies of Vygotsky (1986), were those which focus on how children learn through their interaction and engagement in social activities; different analyses of the culture and language of scientific communities (e.g. Latour &Woolgar, 1979); and discourse analyses of people in specific situations and their interpretations in different sociocultural settings (Tannen 1996, Gee 1991). According to this sociocultural turn in learning theory, pupils come in contact with new ideas within a social context, as they cannot possibly be communicated in another way (e.g. speech, written language, images etc.) (Scott *et al*., 2007). Sociocultural perspectives also focus on dialogue among members of the scientific community. For these researchers, scientists form into communities that use shared linguistic and social rules, values and practices, and ideas and interpretations. Scientific knowledge is thus a product of such scientific communities, and science can be interpreted as the 'social language' that has developed within the scientific community in general (Scott *et al*. 2007). Scientific language includes specific concepts and models that describe the many phenomena of the world, and that can be expressed in different ways (via mathematics, graphical presentations, etc.). Scientific concepts and models derive from the continuous development of theories that apply in a specific area of the physical world (Scott *et al*., 2007), but all of that scientific registry is tied to a given social, cultural and historical context, tying all scientific *understanding* to time and place.

In the school context, pupils come in contact with "school science", a purposively transformed knowledge that describes a range of interlinking scientific concepts and models in ways that pupils of various ages are likely to understand. Therefore, learning of science is about learning the social language of the "school science" (Leach & Scott, 2003). In spite of the very best intentions in transforming scientific knowledge to school learning, the difficulties that pupils have in learning physics derives in part from linguistic conflicts that pupils encounter between scientific discourse and "daily" discourse (Anderson, 2007). Within sociocultural perspectives that focus on science learning, 'alternative concepts' (of scientific concepts) are therefore conceived as representations of phenomena investigated by science but given to cognition by way of everyday social discourse; that is, they are acquired in *ordinary* communication with other people (Scott *et al*., 2007), who are of course not typically scientists.

Both individual perspective scientists and sociocultural perspective scientists are trying to develop theories on how humans learn science. Individual perspectives focus on the individual while often ignoring the importance of the social effects on learning, while the sociocultural perspectives focus on collectives, while often ignoring the importance of individual psychology in acquiring knowledge. What Driver *et al*. (1994) and Leach & Scott (2002 and 2003) are proposing, in their attempt to redress both partial views of science learning, is a new model of learning under the general umbrella of social constructivism. In their proposals, the first part of the term social constructivism, "social", refers to the *social parameters* of scientific knowledge, whereas the second part, "constructivism", refers to the fact that knowledge is a product of *individual construction*. They are thus trying to combine ideas connected to both the individualistic and sociocultural perspectives, creating a model that suggests that pupils should both experience the physical world and be enculturated in the scientific communities by coming in contact with the concepts and models of scientific discourse. The enculturation element of learning (including grasping key attributes of scientific theories) is very important, because this is the only way in which the construction of knowledge can move on from past empirical discovery (Driver *et al*, 1994). Scientific learning is thus considered to include passage from a social (shared) to a personal (internalized) level of scientific knowledge, and this passage is mediated through language (Driver *et al*, 1994).

In addition, Cobb (1994) and Hewson *et al*.'s view (1998) that individual and social constructivism refer to different but complementary dimensions of learning, is very important. In their view, knowledge is constructed on a personal level, but its sharing takes place on a social level (Hewson *et al*., 1998), thereby foregrounding a dialogical understanding of knowledge as the product of social interaction. Summarizing influential literature in the field (Hewson *et al*., 1998; Duit & Treagust, 1998; Driver *et al*., 1994; Halkia, 2008; Hodson & Hodson, 1998; Palincsar, 1998), we can summarise some of the strengths and weaknesses of a social constructivist model of grasping natural science knowledge. The model:

- Has demonstrated the power of "everyday" thinking about natural phenomena, and its resistance to every attempt of its modification to a "scientific" way of thinking.
- Has pointed out the important role, in learning, of the socio-cultural level of pupils, their motivations and interests.
- Has motivated researchers to expand their operations on the documentation of pupils' alternative ideas about various phenomena of the natural world, which has resulted in an available database of these ideas today.
- Proposed promotion and reconstruction strategies of these alternative ideas according to scientific models of correctness.

On the other hand, the weaknesses of this model include:

- Its application, requiring much longer teaching time than other pedagogical models (the development, articulation and reconstruction of ideas takes a long time)
- The possibility that often teachers avoid it, because they do not have the appropriate training, they are not supported in this approach by state policy (for example, it is not included in the curricula, there is no appropriate educational material, etc.), and they have to spend significant additional time on its organization and preparation

- Its frequent difficulties to reconstruct all pupils' ideas. Especially during the early ages, it is common for most of the pupils' simplistic ideas to be only partially reconstructed into more sophisticated conceptual ideas (become similar to scientific ones). This means that the complete reconstruction of the ideas will take place at a later stage, when pupils will have developed the necessary skills to accomplish it then. Teachers, however, become disappointed because they want to see quick results.
- That the whole process of reconstructing understanding from alternative to scientific is experienced as slow and strenuous, resulting frequently in pupils becoming tired of it.

1.3. Conceptual change and alternative ideas

Before they attend school, children are likely to have formed some opinions about natural phenomena and have often tried to give their own interpretations to them (Driver et. al, 2000). In school, pupils come in contact with new scientific information, but all new information is filtered by old alternative perceptions (or preconcepts) they have developed. The questioning, reconsideration and reconstruction of the ideas they have created requires a lot of effort. Moreover, conceptual change is likely to occur only by way of triggering *cognitive conflicts* (Anderson, 2007). Some of the ideas that pupils have created for the physical world are opposed to scientific explanations that they learn in school. Several names have been given by researchers to this clash of ideas (e.g. alternative concepts, preconcepts, misconceptions, conceptual errors, spontaneous concepts, intuitive ideas, previous ideas etc.), but the most predominant term is *alternative ideas*, a term first introduced by Driver & Ealsey (1978). With this term, they wanted to point out the fact that these ideas are personal perceptions that help children to give meaning to and make sense of the environment they inhabit. Their application is related to the natural phenomena that they perceive with their senses and are alternative only in the precise sense of being different to the ideas and concepts of scientists, which can often explain the same phenomena in ways that do not depend solely on our senses (Driver & Elsey, 1978). These alternative perceptions are however deeply embedded in pupils' minds, and they often require time to change their understanding. This is because alternative ideas are not accidental mental constructions; they instead contain an understanding of the world that is both very reasonable and highly consistent and may often stem from their own personal experiences (Driver *et al*., 1994). On several occasions, pupils realize some things with regards to some specific conditions, while on other occasions, they are not complete interpretations but scrappy and incoherent ideas. The creation of those ideas depends on a variety of factors such as, for example, their background knowledge or their mental perception about the world according to their culture (Kuiper, 1994).

It is thus important to emphasize that children's alternative perceptions for various natural phenomena are not arbitrary constructions, but they are incorporated into conceptual structures that provide a logical and coherent understanding of the world from them (Osborne & Gilbert, 1980). However, pupils' alternative ideas are different from scientific concepts, as they are basically descriptive opinions for the phenomena of the natural world that pupils attempt to interpret based on their personal experiences. While scientific knowledge is instead based on the theoretical perception and assessment of phenomena, it does not arise from the pupils' empirical experience. Alternative ideas can often also be created under the influence of external factors. Everyday language can be such a cause, as language is often used in a different way in everyday life than in science (Louisa *et al*., 1989). For example, the commonplace instruction to "close the door to keep the heat in and not get cold" implies the view that there are two physical quantities, heat and cold, on either side of the threshold; in reality, energy is transferred between matter, but our bodies sense this transfer as involving two physically separate entities. Children's communication with adults, or with children of the same age, can all too easily reproduce such misunderstandings. Furthermore, the media also play a major role in the reproduction of such misconceptions (Schoon, 1995). Pupils watching cartoons—where natural laws are often explicitly absent or violated—are likely to develop ideas about the principles of natural laws that do not correspond with scientific knowledge. Most pupils are not willing to easily abandon them, because their ideas are based in logic and sometimes they are not relinquished even after teaching sessions (Ravanis 1999, 2003; Tiberghien 1988; Tiberghien *et al*. 1995). Instead, alternative ideas may remain until

children reach adulthood. This happens, because they are not simple misunderstandings that they may have due to inaccurate information, but they are generated by their mental mechanisms in an effort to understand and interpret their external world (Kokkotas, 2004). Besides, studies in the field of natural sciences have proved that it is a global phenomenon for pupils regardless of their backgrounds and cultures (Duit, 1998).

1.3.1 Summarized characteristics of alternative ideas

Summarizing these and other studies (e.g. Psillos *et al*. 1987;Tiberghien 1988; Tiberghien *et al*. 1995; Wandersee *et al*. 1994; Ravanis, Koliopoulos, & Hadzigeorgiou, 2004; Pfund & Duit 1998; Ravanis 1999, 2003; Fassoulopoulos *et al*. 2003; Kariotoglou 2006; Koliopoulos 2006), we can draw the following conclusions:

a. Pupils who join school (even the elementary school) already have formulated some "opinions" about the natural world and it should not be considered that they "know" nothing ("tabula rasa" theory- the mind of pupils is a blank slate (tabula rasa) which is filled with knowledge through the intervention of teaching and some kind of education
b. Alternative ideas of pupils are highly experiential, and so are durable and resist challenge. They depend directly on their sensory perceptions and their individual experiences.
c. They are however usually incompatible with corresponding scientific concepts.
d. Alternative ideas of pupils are characterized by universality. Pupils of different cultures, socio-economic classes, gender, but also age, have similar concepts about concepts and phenomena of natural sciences
e. These ideas are unconscious. Most pupils are unaware of the ideas they have, and therefore of their explanations about natural phenomena
f. They are often coming from the fact that pupils use cogency thinking (at a local level) to explain a phenomenon. For example, pupils do not interpret two equivalent natural situations in the same way: heating the water on the burner and cooling the water inside a glass with ice cubes. In the first case, they consider that the active source of heat is the burner, which warms up (heat is transferred) the water, while in the other case they consider that the ice cubes keep the water cold ("coldness" is transferred to it).
g. The alternative ideas of pupils are coherent, meaning that they interpret "reality" satisfactorily, so pupils are not willing to abandon them easily.
h. Daily language may be the reason for creating alternative concepts by pupils. This is due to the fact that the meaning of a word varies according to whether this word is used in the context of everyday life or in the context of science. In the case of sign language, something similar can be present. The usage of a sign under specific contexts and the difference between using the sign in daily signing and in formal signing, can create misconceptions in children regarding scientific concepts. For example, in Greek sign language, the sign for "Heat" is the same as the sign for "Hot", whereas the sign for cold is different. This may possibly lead to the idea that heat is connected only to the concept of "hot" and that "heat" is not existent in cold settings.

1.3.2 Conceptual change

But what do we mean by "conceptual change"? According to Chinn and Brewer (1998) and Vosniadou (2007), we need to document children's perceptions for a specific topic in two different time periods in order to determine what conceptual change is. Only comparison of two distinct periods in emergent understanding can guide us in the determination of conceptual change. These researchers thus consider that "conceptual change" is any alteration in the cognitive background of the pupil, involving either addition of new knowledge, or subtraction, or modification, or replacement, of concepts.

In order for pupils to change or to overcome alternative ideas, certain conditions must be met. For example, they should realize that their explanations or their description of a phenomenon are not satisfactory. They must be open to new proposals and have the appropriate background to comprehend the new conceptual framework which is presented to them (Strike & Posner, 1985). Strike and Posner named and categorized these conditions, noting that in order to trigger conceptual change, the following conditions must be met: the *pre-existing* idea should no longer satisfy the pupil (dissatisfaction); while

the *new* idea must be understandable and reasonable (intelligibility); the new idea must be convincing (plausibility); and the new idea should be productive and useful (fruitfulness).

1.4. Didactic proposals of the social constructivist model

Although we can underline that the teaching process in the social constructivist model is not a linear procedure, we can generally describe some basic teaching phases as presented by Driver and Oldham (1986), assuming that these phases are self-evident and need no further explanation. They are therefore listed here merely as phases also pursued in this study's teaching intervention. The same comment applies to the next sub-heading on the role of the teacher.

1. Orientation of the pupils: the teacher refers to a daily phenomenon to intrigue pupils and orient them in the subject that they will discuss.

2. Projection of pupil's alternative concepts: The pupils express their opinions in response to a trigger. They discuss and argument about their ideas and negotiate them with their classmates. The ideas are documented in order to help them understand how there are thinking about the issue.

3. Introduction of the new knowledge: They engage in different activities that will help them take control of their alternative ideas. Experiments are conducted, scientific inquiries, hypothesis processes, observations are some of the activities that pupils engage before they come in contact with the scientific language and explanations. In this phase, the pupils may face ideological conflicts that may lead to conceptual change.

4. Application of the new ideas: In this part it is suggested that the pupils apply the new knowledge that they obtained from engaging in the activities to see how efficiently they understand specific phenomena.

5. Review (meta-cognitive phase): The pupils are comparing old and new ideas with the purpose of realizing their learning process.

The plans that were developed in this research are based on the phases that were described briefly above.

1.5. The role of the educator in the SCM

In the model of constructivist learning, the teacher has to play an equally demanding and decisive role. His/her main objective is to introduce and support the use of new knowledge on the social level of the classroom, so that scientific knowledge becomes "common knowledge" (Leach & Scott, 2003). According to (Leach & Scott, 2003; Mackintosh, 1994; Halkia, 2008), the teacher:

- Knows the scientific concepts and natural phenomena that are going to be taught in a specific course.
- Helps pupils to realize – through dialogue- that new knowledge is more functional for the interpretation of phenomena than their daily knowledge
- Helps pupils to navigate and realize their overall cognitive progress about the specific course: what they knew before (alternative ideas) in relation to what they know now (scientific concepts). This means that he/she helps pupils to develop their metacognitive and reflective skills.
- Has the role of navigator, facilitator and director of the teaching process and analyses the abilities and interests of the class. The teacher is responsible for provoking curiosity by engaging pupils on hands-on activities and encourage them to investigate and think critically of different problems.

1.6. The role of motivation in conceptual change

Generally, motivation has been defined as "energy or drive that moves people to do something by nature" (Han & Yin, 2016). However due to the complexity of the term, there is no universal consensus in the understanding of motivation, thus the existence and the development of various motivational theories. If we consider the general definition of motivation, we can say that motivation is a theoretical concept created to provide causation in human behavior. Pintrich, Marx & Boyle (1993) suggest that the most important motivational behaviors in the classroom context is "choice of a task, level of engagement or activity in the task, and willingness to persist at the task".

The article of Pintrich, Marx & Boyle (1993) had a big influence in the understanding of the CCT. They are one of the first authors that think beyond a cold constructivist model about learning in the classroom and introduce motivational factors in the process of conceptual alteration. According to their opinion, apart from the cognitive processes that occurs in pupils' learning, motivational factors such as goals, intentions, purposes, expectations, or needs may play an important role in pupils' learning. They explain that the way that a pupil perceives a school problem (task), defines it and attempts to solve it, is a matter of individual choice and every personal choice on how to view a problem, is influenced by personal characteristics such as intentions and beliefs. There are numerous motivational factors that may influence the quality and the speed of a pupil's cognitive processes. Pintrich, Marx & Boyle (1993) in their attempt to connect motivation and cognition, propose and analyze two general motivational factors in terms of achieving conceptual change. The first takes into consideration the "motivational beliefs about their [pupils] reasons for choosing to do a task (value components that include goal orientation, interest, and importance)" and the second factor concerns "their beliefs about their capability to perform a task (expectancy components that include self-efficacy, attributions, and control beliefs)." Brief description about each aspect will be provided, as it is an important part of the analysis of the interviews that were conducted in this research.

1.6.1 Goals and conceptual change

"Goals are cognitive representations of the different purposes pupils may adopt in different achievement situations." (Pintrich, Marx & Boyle,1993). According to various researches (e.g., Ames, 1984; Dweck & Leggett, 1988; Elliot & Dweck, 1988; Maehr, 1984; Nicholls, 1984 as cited in Sinatra &Mason, 2008), goals are divided in two categories: mastery[3] and performance[4] goals. Researches on the subject (Dweck & Leggett, 1988; Pintrich,2000; Smiley & Dweck, 1994; Nolen, 1988; Graham and Golan, 1991) argue that the pupils that have mastery goals tend to use deeper and more elaborate strategies as well as metacognitive and cognitive engagement. On the other hand, pupils with performance-oriented goals present lower levels of cognitive engagement and element of superficial learning (Pintrich & Garcia, 1991; Wolters, Yu, & Pintrich, 1996). In regards to conceptual change, studies indicate that it is more likely that pupils with mastery goals to achieve the deep cognitive process required by the model and the probability for the four conditions to occur in conceptual change is higher (Linnenbrink and Pintrich, 2002).

Interesting is the thought that pupils' goals are created and developed according to the socio-cultural and classroom context (Elliott & Moller, 2003; Qian & Pan, 2002 as cited in Sinatra & Mason, 2008). In the case of deaf pupils, an important role in developing goals is the expectations that they have about themselves as well as the expectations that others have about them. Many pupils, as well as teachers, believe that deaf pupils cannot reach complex cognitive processes, especially in science learning because of their deafness. In many cases, societal norms do not inspire deaf pupils in creating mastery goal in science, because the future careers that are expected of them (manual jobs mostly) do not include science understanding (Harris, 1995).

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3 Pupils with mastery goals are characterized by their intentions to understand deeply the task, because they deem that the knowledge is important to them in the future (Pintrich, Marx & Boyle,1993).

4 Pupils with performance goals are interested in outperforming their peers and/or achieving good grades.

In conclusion, goals are considered very influential when it comes to the pupils' choice in using superficial or deep cognitive and metacognitive strategies.

1.6.2 Interests, importance and conceptual change

Different studies on the learner's characteristics and conceptual change indicate that interest plays an important role in learning and cognitive processes (Pintrich, Marx & Boyle,1993; Sinatra & Mason, 2008; Murphy & Alexander, 2008; Nolen & Haladyna, 1990). Interest in a subject or an area can influence also the perception of importance. For example, pupils may present interest in science because they think that understanding scientific concepts will influence their possible future careers (Pintrich, Marx & Boyle,1993; Sinatra & Mason, 2008). The value beliefs and interest about a subject, therefore, can influence the creation of mastery or performance goals (Pintrich, Marx & Boyle,1993; Sinatra & Mason, 2008). It is important to mention that value beliefs of a task in a subject (e.g. a project or a problem) are personal characteristics that pupils attribute to the tasks and not features of the task itself (Pintrich, Marx & Boyle,1993).

According to Pintrich, Marx & Boyle (1993), interest is connected to "to the pupil's general attitude or preference for the content or task (e.g., some pupils just like and are interested in science)". At the same time interest is connected to value beliefs of the pupils, most important of which are "utility value" and "importance". According to their definitions:

Utility value concerns the pupil's instrumental judgments about the potential usefulness of the content or task for helping him or her to achieve some goal (e.g., getting into college, getting a job). Finally, the importance of the task refers to the pupil's perception of the salience or significance of the content or task to the individual. In particular, the importance of a task seems to be related to the individual's self-worth or self-schema. If a pupil sees himself or herself as becoming a scientist […], then science content and tasks may be perceived as being more important […]. (Pintrich, Marx and Boyle, 1993, pg. 17)

In the case of deaf pupils, many studies (DeCARO, Dowaliby, & Maruggi, 1983; Napier & Barker 2004; Naidoo, 1991; Jambor & Elliott 2005) indicate that not many pupils believe in achieving to enter college and become scientist, due to linguistic difficulties or the belief that their linguistic needs at the university level cannot be supported. This results in low self-expectations and low levels of interest and importance value in the subject of science. Apart from the pupils' expectations, teachers' beliefs also play an important role in mediating an interest in science among deaf pupils. If the teachers do not believe or expect deaf pupils to become scientists in the future, then the pupil loses interest in understanding scientific ideas. (Naidoo, 1991)

Cultivating interest and the sense of importance in deaf pupils towards science is very important, as personal interest is responsible for "pupils' selective attention, effort and willingness to persist at the task, and their activation and acquisition of knowledge." (Pintrich, Marx & Boyle, 1993, pg. 17). Specifically, when it comes to deaf pupils, there is not enough literature that connects how personal or situational interest influences the cognition of deaf children. However, drawing upon the study of (Mackintosh *et al*.,1994), deaf children seems to have lower motivation than hearing children in learning about science due to external factors (e.g. parents and teachers expect that deaf children cannot understand complex scientific concepts). Therefore, by increasing the situational interest of deaf children in science learning, there is a possibility that the personal interest and self-esteem of these pupils in choosing careers in science will also be improved, as interest is very closely related to goal orientation. To the extent of conceptual change that requires complex cognitive processes in accepting alternative views, interest and utility values mediate the process in accommodating the new, conflicting opinion.

Apart from personal interest, Sinatra & Mason (2008) refer to the situational interest that is more specific to the classroom and task that the pupils have to perform in the science subjects. Situational interest is controlled more easily by the teachers and there are different tools that can increase or decrease it. For example, the feelings of surprise, challenge, choice and fantasy can contribute to the augmentation of situational interest. Situational interest can also influence pupil's cognitive performance. However, it is more specific to different tasks rather than the personal interest, which is in a more general framework towards science.

1.6.3 Emotions and conceptual change

Sinatra & Mason (2008) describe how the emotions of the pupil can influence the conceptual change process in science classes. First of all, the provide a definition of emotion by quoting Rosenberg (1998), which defines emotions as "brief, psychophysiological changes that result from a response to a meaningful situation in one's environment". This definition is important when we can distinguish emotions from the meaning of "mood", which is more general, last for days and maybe influenced by other circumstances that not necessarily connected to schooling. However, specifically the emotions that are going to be described here, can influence the cognition and performance of a pupil, thus conceptual change teaching.

Academic emotions[5] have a very strong effect in conceptual change, thus it is rendered necessary to investigate this parameter when we discuss the alteration of pupils' ideas in science education. Pekrum *et al*. (2002, as cited in Sinatra & Mason, 2008) stated that emotions can be described and divided in two categories. The below table concentrates the categories of the emotions as described by Pekrum *et al*. (2002) and Sinatra & Mason (2008).

Table 1. Categories of emotions and their effect on learning

Valence level / Activation level	Positive	Negative
Activating	**For example**: enjoyment, pride, hope **Effect:** They have positive effect on academic achievement by increasing motivation, critical thinking, elaboration, and metacognitive strategy use	**For example**: anxiety, anger, shame **Effect:** They can also be beneficial to academic achievement because they may increase the pupils' motivation to carefully process the information in order to ultimately succeed with the learning task.
Deactivating	For example: Relief **Effect:** They may temporarily reduce cognitive processing, but over the longer term, positive responses may increase motivation to continue putting forth cognitive effort towards the task.	**For example**: Boredom, hopelessness **Effect:** They diminish motivation, direct attention away from the task, and can result in superficial cognitive processing

Clearly, the promotion of positive activating emotions is the ideal when teaching with conceptual change methods. However, both positive and negative activating emotions can possibly aid the process of conceptual change if they help increase the motivation and focus, promote persistence in the task and augment positive self-beliefs and mastery-goals.

5 Emotions that are connected with "pupils' responses to studying, test taking, and other classroom activities" (Sinatra & Mason, 2008)

In conceptual change the existence of both positive and negative emotions is preferable. In order to have cognitive conflicts, the pupils need to connect prior alternative concepts with negative emotions that create doubt and positive emotions towards the new ideas in order to achieve a possible alteration. The connection of prior alternative ideas to positive emotions and moods can impede conceptual change. Negative activating emotions (such as stress) can be productive if combined with high self-efficacy (Sinatra & Mason, 2008).

1.6.4 Self-efficacy and conceptual change

Self-efficacy can be another possible reason that influences children's motivation in changing their misconceptions about scientific concepts according to Pintrich, Marx and Boyle (1993). According to them, self-efficacy refers to pupils' beliefs about their performance abilities to finish a task or complete a goal. In the conceptual change aspect, self-efficacy can be described as pupils' confidence in their capabilities to perform a specific task and thus their confidence about their own concepts. In practice, the higher confidence pupils have about their alternative ideas, the more this impedes the process of conceptual change. In a second view, self-efficacy can be also described as the confidence that pupils have about their ability to alter their perceptions and thus synthesize richer cognitive structures. In this notion, self-efficacy influences children's trust in controlling their own learning and their thinking strategies.

Strike and Posner (1992) in their research about self-efficacy reported that pupils' learning attitudes[6] are connected with conceptual change. In their study they indicate that the more confidence pupils have in their capability to understand science and approach scientific ideas, them more likely is to present conceptual change. Pintrich, Marx & Boyle (1993) state that one of the best ways to increase self-efficacy among pupils is not merely to leave children to confront their cognitive conflicts on their own, but to support them with modelling and verbalization of appropriate strategies of thinking. In this specific case the mental model presented in the story is placed there to help pupils increase the value of their strategies by creating mental representations of the movement of heat, thus increasing pupils' confidence in providing explanations of their thinking.

1.6.5 Control beliefs and conceptual change

According to Pintrich, Marx & Boyle (1993) control beliefs play also a major role in the motivation of the learner and the potential conceptual change. They define control beliefs as: "individuals' belief about how much control they have over their behavior or the outcome of their performance" and they distinguish control beliefs from self-efficacy by highlighting the importance that environmental and outcome expectations play in the perception of control learning from a pupil. The authors clearly state that there is a connection between conceptual change and pupils' sense of control of their own learning. They argue that the perception of control of learning can influence the acceptance or accumulation of new, scientific ideas. If pupils believe that they do not have control, then they are less willing to bridge the gap between the prior ideas that they hold and the new divergent ideas that they are coming in contact with. In this way, pupils might view scientific views as something beyond their realm of understanding, something that is being taught by the teacher and they cannot influence or process this knowledge. On the other hand, pupils that have strong control beliefs are more willing to engage in the process of understanding scientific ideas (ibid.).

In the case of project-based learning that include a problem with a specific question that has a goal to drive and organize activities, conceptual change instruction gives various opportunities for pupil control (ibid.). In the case of the project designed for the purposes of this research, pupils can choose how to work on the final product (the construction), what material to choose, and what kind of information they will take advantage of. This process gives the freedom to control how they want to manufacture the final solution to the original problem that was assigned to them. The choice of which experiment they want to conduct, provides them the opportunity to think critically about which of the experiments

6 "Attitudes" is a word that describes the four concepts connected to motivation (goals, interest, beliefs, self-efficacy)

will help them in the final stage. Therefore, pupils have the freedom to choose the experiment and the way to conduct it (with real material or watch it digitally).

1.7 Didactic tools

Various tools are used which aim to provide a smoother approach to knowledge to the pupils, in order for them to enjoy the best possible learning outcomes. Such tools include the questions, the dialogues, the mental representations, the metaphors and analogies, the problem-solving situations and the practical work, all of which are included in the design of the teaching sessions.

1.7.1 The questions

Questions, during teaching sessions, are considered a very important teaching tool, as they aim to highlight the pupils' inner beliefs and enhance the expression of their personal opinions within the school context (Gall, 1970). Basing themselves on a text or an image or an observation, pupils respond to questions asked by either their teacher or their classmates, in order to express their views and create a dialogue within the classroom.

1.7.2 The dialogue

The teacher in his/her attempt to highlight pupils' views and ideas can introduce the dialogue. In a collaborative and democratic environment, dialogue is a valuable tool. The pupil, conversing with his/her classmates or through a conversation inside the classroom, can listen to ideas he/she had never imagined before, express his/her views and argue them, and even realize any contradictions of his/her or his/her classmates' opinions. (Wells & Arauz, 2006) Besides, as Driver et.al (2000) informs us, "according to general opinions, knowledge is a link between the appropriate questions and the right answers".

1.7.3 The analogies and metaphors in science teaching

It is characteristic that many pupils when they are posed with a problem that they do not know the solution, they recall a familiar (to them) problem and its respective solution and try to solve the first problem accordingly (Coll, 2015). This technique is called analogous reasoning.

The difference between analogy and metaphor is slight and a metaphor often coexists with an analogy. The terms "metaphorical" and "analogical" thinking have substantial similarities to the extent that the analogy can be considered a necessary condition for the metaphor. The only thing that distinguishes them is that in a metaphor we mean that A is B, whereas when we use an analogy we say that A looks like the B.

Metaphors and analogies are used when we want to compare two things, which we want to have both similarities and differences. The pupil starts from something familiar in his/her own mind and get information which describes something that there are not familiar with. With metaphors, we focus more on the similarities between two things or concepts, while with analogies similarities and differences are discernible. They are a useful thinking tools, which enables pupils to create models. They are tools that we use to explain our thoughts and ideas to others about a scientific topic (Duit, 1991). They are something like a bridge between the scientific and the everyday language, making the science more understandable and accessible. Teachers often prefer analogies to make a scientific concept more visible and familiar for their pupils instead of being abstract in their minds (Duit, 1991). The teachers' purpose, in this case, is to help pupils to build a mental representation in their minds or a model for concepts that are abstract to them.

1.7.4. Cognitive representations

Pupils often have the ability to remember images of objects, phenomena and events when they study something abstract and vague. These images, called representations (or models), can either come from

their knowledge on the concept they study or from knowledge transfer from something that is similar to that concept (Johnson-Laird, 1983). They are cognitive strategies the pupil uses when he/she faces a new situation or when he/she wants to memorize a specific situation. Cognitive representations are dependent on the pupil himself/herself, who is not aware of them and use them to become familiar with and interpret their environment (Franco & Colinvaux, 2000). Cognitive representations are personal in relation to mental models that are broad and introduced to the pupil by the teacher or textbooks in order to be able to think and understand better some abstract concepts (for example, the Watson-Crick model of DNA or the Rutherford's Planetary Model of the Atom, etc.).

1.7.5. Problem solving

According to the theory of knowledge construction, learning through problem-solving is a very effective approach for teaching a phenomenon or a concept of natural sciences. This strategy is applied more to groups of children and less at an individual level, since it is preferable for children to be able to negotiate their ideas with their classmates, but also to come into contact with ideas that they have not previously thought of (Heller, Keith & Anderson, 1992). The role of the teacher is advisory and he/she will shape the structure of the teaching session in such a way that the solution to the problem will come out naturally. Problem-solving is a form of discovery, active and experiential learning from which pupils learn effectively by studying works that emerge from their everyday lives and are interested about them (Tuma & Reif, 1980). Pupils take responsibility, take initiatives and practice creative thinking. Problem-solving is a means of teaching about many scientific ideas because it allows multidisciplinary activities to be included in the curriculum (Kokkotas,2004). Therefore, teaching with the problem-solving process besides being interesting and accessible to pupils is also a multidimensional tool that allows the teacher to integrate it in the context of interdisciplinarity (Jones, Rasmussen, & Moffitt, 1997). In terms of conceptual change, Loyens *et al*. (2015) conducted an experiment that indicated that children presented change in their concepts more effectively than attending a lecture or self-study.

As far as deaf education is concerned, teaching with problem solving is rendered necessary. The knowledge is connected to the children's world, thus making learning science meaningful for the pupils. Mackintosh *et al*. (1994, pg. 4) characteristically state that deaf pupils "might be less likely to have experienced "normal, unstructured" play in which incidental learning occurs, due to the structured scheduling of continual speech lessons, audiological evaluations, extra tutoring, and lack of experiential schema." Through problem-based learning D/HH pupils have the opportunity to investigate their own solutions away from the textbooks, thus earning confidence in their own skills. Research (Hung, Jonassen & Liu, 2008; Savin-Baden, 2003; Savery & Duffy, 1995; Kwan, 2009) indicate that problem-based learning can increase motivation and at the same time develop fantasy and train the argumentative skills of pupils. This is why the plans that are prepared in these teaching sessions begin with a problem that pupils need to provide a practical solution based on hands-on work.

1.7.6. The practical work

The field of natural sciences allows and encourages experiential work, especially when it is implemented by research, discovery and problem-solving activities. Practical work is best associated with problem-solving, which gives to the teaching a more experiential tone as it comes in contact with the everyday world of children and prepares them for any challenges they face. Pupils have the ability to apply what they learned from books and learn even more. They realize the difficulties faced by scientists and conduct different types of research in order to overcome them. Besides the practical part, the discussions that take place simultaneously with it, the exchange of ideas and several suggestions play a big role in the effectiveness of science understanding (Woolnough & Allsop, 1985; Hodson, 1990; Abrahams & Millar, 2008).

Many studies about science learning in special educational classes (Scruggs *et al*., 1993; Mastropieri & Scruggs, 1994), indicate the importance of hands-on experience, experiential learning and practical work. In deaf education, which is a part of special education in Greece, experiential learning and hand-on tasks are promoted by the curriculum, especially in science teaching classes. Quoting a translated version from the suggestions presented in the curriculum for the deaf: experiential learning "enriches

pupils' experiences, develops their imagination, cultivates their language skills, reinforces the consolidation of the knowledge and awakens their artistic skills".

A big part of the project that was created especially for the pupils of the Deaf schools was the final construction, which demanded the pupils work in a practical way. By implementing the theoretical knowledge from the story and the experiments, the goal of the pupils' practical work was to see if they can understand the difference between materials that conduct or insulate heat. The materials for their work were provided by the researcher and every school was provided a variety of materials (both conductors and insulators) in order to give the opportunity for pupils to think critically about the choice of materials in their construction. More specifically, every school received the following materials: sponges, plastic bags, plastic with air bubbles, woolen fabric, three boxes (paper, plastic and wooden), a metallic pot, aluminum foil, metallic and plastic wire, rope, tape, glue, scissors, toilet paper rolls, insulating tape, wooden planks, cork, cotton, newspapers, corrugated paper, Play-Doh, toothpicks, rubber bands, and thick white papers.

1.8 Cooperative approach in science teaching

Natural sciences' teaching is characterized as a process of interpersonal interaction and it is recognized that verbal communication is the main factor of this interaction (Matsagouras, 2008). This verbal communication is achieved more effectively when pupils work in an environment of teamwork and cooperation. Due to their communication, pupils can be helped both at an individual and a collaborative level, contributing to the learning of the other members of the group. According to research findings (Matsagouras, 2008, 2009, Blough, 1957, Johnson & Johnson, 1986), when pupils work in a team context, they achieve their goals more efficiently and there is more effective learning, especially in demanding subjects such as natural sciences. The pupil's socialization within the group favors the development of thinking, while it motivates and engages them in processes of taking up responsibilities and initiatives. The pupil, who will be participating in a team, is more easily motivated compared to a pupil who works on an individual level because the individual feels responsible towards the team (Johnson & Johnson, 1986, 1994).

Especially in the field of natural sciences, group collaboration is a catalyst for more effective resolution of problems that may be posed by the pupils' teacher or their social environment (Johnson & Johnson, 1986, 1994). When pupils have to observe a phenomenon as a group, learning is more complete, as pupils receive different views about a concept beyond their own, which makes them open-minded and perhaps leads them to conceptual change. Therefore, the individual boundary of their thought and act is overcome, something that would not happen if they worked individually. Pupils, through conversations, exchange more information than they would have reached if they were alone, while the decisions taken through teamwork lead to their degradation of selfishness and promotion of commitment inside a group (Johnson & Johnson, 1986, 1994, 1998). Pupils perform group experiments, study the data, come to conclusions and finally present their work inside the classroom.

According to Kuhn (1970 in Kokkotas, 2004), knowledge of natural sciences is a social construct, albeit scientific discoveries are performed through social interactions rather than an "intelligent" individual. According to this, classroom organization into groups and pupils' interaction with each other are necessary components for pupils to gain knowledge. Information exchange among the members of a group is important if they want to be on the same track. Therefore, what is accomplished is something like a teaching exchange between the children that is very helpful for them. If we consider that in the traditional model the pupil receives stimuli only from the teacher who is considered an expert, in the collaborative model the pupil not only listens to his/her teacher's and classmates' views, but also come into contact with a large amount of data and information (Matsagouras, 2008,2009).

In the deaf education framework, cooperative education practices have been shown to develop membership and a sense of belonging among pupils (Antia, Stinson, & Gaustad, 2002), to help them achieve higher performance, obtain a sense of success (O'Donnell & Adenwalla, 2004), to raise their self-esteem and to improve their communication skills.

Chapter 2: Children's alternative concepts about heat and thermal conductivity

Several studies have turned their focus on how pupils conceptualize the concept of heat and the other concepts that are connected with heat. Researchers such us Erickson (1979), Driver (1981), Driver (1985), Duit & Kesidou (1993), Lewis & Linn (1994), Harisson *et al* (1999) have conducted research on children's alternative ideas regarding the concepts of heat and thermal conductivity. From these studies, it is concluded that the pupils attribute different definitions about the notions of heat and thermal conductivity from the ones that the scientific community has. Furthermore, these alternative ideas can be found in people that are attending different kinds of education (primary/secondary education, special education, higher education). These alternative ideas seem to be primarily a product of the daily experiences and ways of thinking and secondarily a result of previous teaching on the subject.

In the generation of these ideas, an important role is played by the language that we use in everyday communication regarding "hot" and "cold". Usually these terms can be used figuratively, thus establishing the alternative ideas of the pupils. Specifically, in the Greek language the word "Thermotita" (=heat in English), includes the word "thermo- "(=hot in English) which leads pupils to associate heat with high temperatures (Halkia, 2008). Phrases such as "Close the door and keep the cold out (or keep the heat in)" for example, separate heat in two entities: "the hotness" and "the coldness" and give the impression that "the coldness" has the ability to "come in" and that we can therefore use the door to block that movement (Erickson & Tiberghien, 1985). Another important reason for the creation of such misconceptions might be that some concepts are relatively difficult to capture, because their description and their interpretation requires further knowledge of related concepts, such as perhaps "energy", in this case (Kokotas, 2004).

The alternative ideas that are presented below describe how children of different ages may perceive the concepts of heat, temperature and thermal conductivity.

2.1 The alternative concepts of the pupils about heat

According to conducted research (Duit & Kesidou, 1988, Erickson, 1979, 1980, Halkia, 2008) about the concept of heat, pupils appear to have difficulties in two areas:

- The nature of heat and
- The use of an entity (heat) or two different entities (heat and cold) to explain thermal phenomena

2.1.1 The nature of heat

There are two concepts about how pupils perceive the nature of heat. Some pupils regard heat as a fluid substance (such as air, smoke or steam), while others perceive it as a movement of matter particles. The latter aspect is perceived by pupils who attend junior high school or high school the concept of molecules is introduced. Pupils have various alternative ideas with regards to the nature of heat, the main ones being:

2.1.1.1 The perception of heat as a fluid substance stored in bodies

Heat for children is a substance that is in a fluid state (like air, smoke or steam) and in this way, it can be moved more easily in whatever direction it wants. It is something that is stored in the objects and forms its physical state. In some cases, pupils consider that this "stored" substance can only "leave" the object when it is warm and emits heat. It is common for pupils to confuse heat with the internal energy or the thermal energy of an object. This fluid substance, according to pupils, has the characteristic of making the object warm when it is stored inside the object, and when it is absent, the object becomes cold. In other words, pupils think that heat affects the thermal state of objects.

2.1.1.2 Heat moves in whatever direction it "wants"

In terms of heat transfer, many pupils claim that heat is transferred from a hot to a cold object, but when it comes to explaining the transfer of heat from our body to an object they argue that if the object is cold, then it transfers heat to our warm hand.

2.1.1.3 Heat is identified with a thermal source and the larger an object's size, the more heat it encloses

Many pupils tend to identify heat with a warm object and do not identify heat in cold objects. In fact, they argue that the larger the warm objects are, the more intense results they have as they contain more heat. We observe that pupils confuse heat with thermal energy or with the internal energy of the objects. It is characteristic that pupils do not see heat as energy being transferred, but as energy contained in various objects and it is even dependent on their size (Hewson & Hamlyn 1984, Wiser 1986, Kesidou & Duit 1993).

2.1.2 Use of one or two notions to explain the thermal phenomena

It has been noted in the literature that there are some pupils who use heat as one notion to explain thermal phenomena, and others who use two entities, "heat" and "coldness" (Duit & Kesidou, 1988, Erickson, 1979, 1980, Linn & Songer 1991, Viennot 1997, Tiberghien 1980, 1983, Shayer & Wylam 1981, Summers 1983, Watts 1983). The perception of heat as one notion appears in pupils aged 12 and above, and it becomes solid as the children get older.

The concept of heat as two notions appears in pupils aged 12 and below, who describe that heat is responsible for heating objects, while "coldness" for their cooling (Erickson 1979, 1980, 1985, Briggs & Brook 1984, Clough & Driver, 1985, Watts & Gilbert 1985, Magnusson 1992, Aiello-Nicosia & Sperandeo-Mineo 2000, Σκουμιός, 2005, Wiser & Amin 2001, Van Roon, Van Sprang & Verdonk 1994). The objects' temperature can be explained by them as a mixture of heat with "coldness". For them, the coagulation point of an object is the limit at which we can distinguish when we talk about heat and when about coldness. Therefore, at temperatures above the coagulation point of an object, we have heat and below the coagulation point, we have "coldness". As far as our body is concerned, they feel that when we touch something warm, then heat enters our body, but when we touch something cold, then coldness enters our body.

2.2 Concepts regarding the conductivity of materials

According to various researches (Tiberghien 1980, 1985, Erickson 1980, 1985, Engel Clough & Driver 1985, Sciarreta *et al*. 1990, Jara-Guerrero 1993, Lewis & Linn 1994, Newell & Ross 1996), the main alternative ideas of pupils are summarized as followed:

- Insulators generate heat
- Conductors attract heat in a warm environment and coldness in a cold environment
- Objects are exclusively either conductors or insulators

2.2.1 Insulators generate heat

Most pupils can explain how insulators, and especially woolen and cotton fabrics, have the ability to absorb or generate heat to warm up our bodies in the winter. Due to their experience, pupils think that the clothes we wear in the winter produce heat for keeping us warm rather than simply slowing the rate of heat leaving our body. Moreover, when we ask pupils on which dish (metal or wooden) we can put a piece of ice in order for it to melt slower, they prefer the metal one, because they claim that metal "generates cold".

2.2.2 Conductors draw heat in a warm environment and coldness in a cold environment

With this notion, pupils consider that a conductor, such as metal, has the ability to attract, maintain or even absorb heat, depending on the environment in which it is located (Tiberghien 1980,1985, Erickson

1980,1985, Tiberghien 1983, Engel Clough & Driver 1985, Kesidou & Duit 1993, Lewis & Linn 1994, Harrison *et al*. 1999, Σκουμιός, 2005). Because of this notion, many pupils believe that because a metal is cold in a cold environment, so it absorbs and maintains coldness, it can also keep something else cold, such as food. Therefore, they often confuse the concepts of an object's temperature and of energy transfer. Many such misunderstandings may also stem from how materials are used in everyday life. For example, aluminum foil is used by many parents to wrap up food in order to take it with them somewhere in order to keep the temperature stable, and because the foil looks metallic pupils are confused and consider metal as an insulator. Tiberghien & Erickson (1985) explain this phenomenon as the tendency of pupils to associate an object or material with a similar situation that they have seen/experience. The same happens in the case of a Thermos flask, which is usually made externally of steel and the pupils without knowing of the other insulating materials conclude that steel has the ability to maintain heat. According to Tiberghien & Erickson (1985), pupils tent to connect "a property of the object with an event (it is cold so it cools)". In case of metal, they usually express opinions such as "the metal is cold, so it produces cold".

2.3.3 Insulators are made to preserve object that are hot or objects that are cold

This is a common misconception from pupils, who usually maintain that containers made from insulating materials are able to preserve an object hot or cold depending on the purpose for which they were made (Clough & Driver,1985, Viennot, 1997). For example, pupils claim that since Thermos flasks are made for preserving hot tea, it is not possible for them to also preserve cold water. It was found that pupils who see heat as two entities find difficult to understand that insulators can prevent the thermal equilibrium regardless of whether the object is hot or cold (Clark, 2006, Arnold & Millar, 1994, Lewis & Linn, 1994)

Chapter 3: Literature review

According to Reed, Antia and Kreimeyer (2008) and Traxler (2000) the average academic achievement of D/HH[7] pupils is considerably below that of their hearing peers. This is because traditionally, the curriculum for deaf learners mainly involved language acquisition. Emphasis on academic subjects, such as science was marginal (Naidoo, 2008). Even if deaf schools had science as a subject, the literature on teaching practices suitable for use with deaf pupils was limited. Most of the deaf education teaching practices in science involve academic, dogmatic and sterile approaches, which are considered by pupils as a collection of facts and laws with no connection to their real lives (Hadzigeorgiou, 2006). There is a need to humanize science and make it more appealing and approachable to deaf pupils. In this part, I will present the current and most influential literature on the topic and I will point the research gap. Due to the fact that I have not found any literature that combines storytelling, science literacy and deaf pupils, I chose to look at these key topics by way of two separate connections between the three main points (storytelling, science literacy, deafness). Therefore, I will firstly present the connection between science learning and storytelling. In the two following sections I will presented the connection between Deaf education and storytelling, and teaching practices in science, respectively. Taken together, the three sections synthesize the topic that I am researching.

3.1 Science and storytelling

Research has shown that the use of literature—stories—in science education is very effective, since pupils have the opportunity to actively be engaged and to gain a better understanding of the ideas that led up to the discovery of certain physical concepts (Hadzigeorgiou, 2006, Negrete & Lartigue, 2004, Klassen, 2009, Kokkotas, Rizaki & Malamitsa, 2010) According to Negrete and Lartigue, 2004, there is a need from educators to find innovative teaching methods that counteract the traditional boring and inefficient approaches to convey science; a new method that presents science as "hard fun" and motivates pupils to take action. They suggest that narratives, stories, novels, comics and fairytales are different and important means for communicating science in order to convey information in an accurate, attractive, imaginative and memorable way (Negrete & Lartigue, 2004). In their review, they underscore the importance of storytelling by claiming that it is "an amusing way to create an interest in science", because stories stay in children's memory easily, their structure is more familiar to them and they use a simple language that enables interpretation and dialogue. Klassen (2009) argues that story structures can lead to conceptual change in scientific ideas and he highlights that science stories may promote "re-enactment of the learning process" and generate motivation for active learning to the pupils. Another study suggests that there are positive effects in intellectual, social and emotional development of children who are encouraged to use storytelling (Mallan 1991).

Fuchs (2015) investigated how stories develop scientific perceptions and models that ultimately lead to scientific theories. He argues that scientific stories create scientific storyworlds (or "conceptual structures (frames) that contain the seeds of scientific ideas" as he defines them) and that storyworlds are the informal counterpart of scientific models. Therefore, the creation of such storyworlds is serving as a facilitator in children's learning especially when the models or concepts discussed are vague (e.g. thermal energy). In the story that the children will read in this investigation, it is proposed a model of imagining the flow of heat in different materials. This is very important as the word "heat" and "energy" are very vague and the model proposed can facilitate and develop pupil's thinking, as it has already

7 The terminology that will be used here is Deaf (which are people that belong in the Deaf community) and Hard of Hearing (which are people with a mild, moderate, or severe hearing loss). The terminology "hearing impaired" is often considered offensive because it does not account for cultural identity (source: http://www.deaflinx.com/DeafCommunity/identity.html).

been concluded from previous research with hearing pupils (Kemou, 2014). So, the matter that should be investigated here is if that positive effects can be also observed in D/HH pupils.

Empirical studies that implement storytelling in different learning settings (e.g. museums, schools) show that storytelling is a helpful tool in promoting motivation for science learning, in establishing a sense of agency, and in serving as a cognitive guide (Murmann & Avraamidou, 2016), whereas other experiments indicated that stories helped in the formation of assumptions, conclusions, and the development of argumentation in scientific matters (Hill & Baumgartner 2009). More specifically, in the study of Murmann & Avraamidou (2016), the researchers used the story "the emperor who only believed his own eyes" in exhibitions in scientific museums in order to see if the story urged the pupils to engage with scientific activities. The scientific area they investigated was human and animal senses, and the pupils were between 10-13 years old. The results from the experiment indicate that the use of the story increased the motivation of pupils to engage and learn more about the scientific theme. Another study by Hill & Baumgartner (2009) used a story in order to teach the "laws of motion" in science. The pupils engaged in a project that was based on the story and they worked in parallel with the hero of the story. The pupils worked on a challenge that was posed by the story, and they ran different experiential activities in order to solve it (gathering of information, experiments, conduct a running game etc.). At the end of their activities the pupils justified the analysis of their data, using the story. The results of the study suggest high motivation in learning about kinetics and high focus on the task, because of the usage of story.

A case study from Plakitsi & Kokkotas (2010) reveals also evidence of the usefulness of storytelling in science teaching. During this teaching intervention, the researchers used a story in order to teach the concept of time. They used parts of the planning that the CCT proposes as they started by recording pupils' alternative ideas and misconceptions on the topic. Then they conducted an interdisciplinary teaching of time for two months using 20 worksheets. They introduced open learning environments inside the class and they incorporated learning strategies such as dialogues, argumentation, scientific controversies in order to provoke conceptual conflict in the pupils. Their results indicate a higher motivation and alteration of the pupils' ideas about time.

In the Greek literature, there are three dissertations that have examined the effects of storytelling in science teaching by conducting action research. The study of Μαργαρίτη (2012) concerned the teaching of the concept of the immersion of different materials using a digital story called "The ant and the dove" in pre-school pupils. She used CCT and constructivism as theoretical background of her study. In the results she observed an improvement in pupils' ideas that approached the scientific explanations. Another teaching intervention from Κουτσιούκης Γ. (2011), based the teaching of the concept of light and its properties in a story in 12-year-old pupils in primary school. The results indicate that after the intervention the pupils showed elevated motivation in learning about the scientific concepts and alteration of the original ideas. The research also used CCT model and constructivist ideas.

3.2 Deaf and narratives

Storytelling is the most common means by which people describe their experiences and organize their lives (Ingber & Eden, 2011). Not only hearing people, but also deaf and hard of hearing (D/HH) people, in their everyday lives, use stories to describe events or parts of their daily routine in sign language (Rutherford, 1985). According to Rutherford, Deaf culture includes different folk traditions, one of the most widespread among Deaf children is narration. Narration is very important to deaf pupils as through stories Deaf pupils find their world views and value system. She described that the narrative approach can act as a teaching tool that can develop Deaf pupil's appreciation of the written language and the world view they contain. Stories have the power to transmit cultural values, folk wisdom and universal truths and they serve as a powerful educational tool that can improve Deaf pupil's conceptual, linguistic and social skills. She argues also that narratives, as a tradition of the Deaf culture, can help Deaf pupils in their cultural validation and in their understanding of the group's behaviors and norms, thus leading to their identity reaffirmation. Rutherford continues by urging teachers to include storytelling to convey difficult concepts and to open a new world to Deaf kids- a world where books are not just about learning grammatical phenomena but learning with the purpose of exploration and entertainment. By adopting

a storytelling practice in Deaf classes, the pupils feel more comfortable as they come across a practice that they recognize and all the other exercises around it are meaningful to them. Storytime usually takes the form of play for the children, thus providing them with more freedom and less fear of committing linguistic mistakes.

Poveda *et al*. (2008) describes that storytelling for D/HH children, interpreted in sign language, can be a great multimodal experience for both Deaf and hearing children. On the other hand, Schick and Gale (1995) highlight the importance of storytelling in deaf communities for providing meaningful experiences and many opportunities for interaction. During storytelling, children tend to be more interested in what is studied, more responsive and highly engaged and motivated.

Although it seems that D/HH people use storytelling in their interaction in sign language and in their cultural traditions, there seems to be a lack of storytelling when it comes to their education. It would be beneficial, therefore, if in Deaf education teachers include parts of Deaf culture, like storytelling, in their lessons; not only in language literacy, but also—as proposed by way of this study—in mathematical and science literacy.

3.3 Deaf and science learning

Science literacy is a problematic area in Deaf education and it has challenged both researchers and practitioners. Available studies show that D/HH pupils have low performance in conventional science learning, due to the fact that it relies heavily on lectures and textbooks (Wang, 2011, Roald, 2002, McIntosh, Sulzen, Reeder, & Kidd, 1994). Wang (2011), in his review of empirical research on science as school subject for Deaf pupils, has argued that conventional science instruction to struggling readers[8] is unsuccessful due to their limited access to printed information in textbooks. For this reason, she supports and proposes a theoretical framework for inquiry-based teaching in science for DHH pupils. According to her theory, D/HH pupils will benefit from having thorough discussions in sign language before the introduction of the scientific ideas, while having science teaching using inquiry-based techniques helps the children make sense of their environment.

Furthermore, according to a recent study, deaf teachers suggest that science learning practices in D/HH schools need improvement and teachers need better understanding of how D/HH learn (Roald, 2002). They revealed in their interviews that they would prefer an open and group-based teaching approach in their science classes, while they consider the method of discussion and cooperation in class very important in learning scientific concepts. The participants also recalled experimenting as positive part of their own education as well (Roald, 2002). Moreover, Easterbrooks and Stephenson (2006) report that the use of sign language in explaining difficult scientific concepts, the creation of active-learning activities and the usage of problem-based instruction methods that require the enablement of critical thinking, should all be important parts of science teaching in D/HH pupils. These important teaching elements were also included in the planning that the researcher did for this study, and that the teachers applied in class in the current study.

Finally, a very important article of McIntosh *et al*. (1994) reported the need to make physics more accessible to deaf pupils. They note that although science is deemed important, it seems not to be prioritized in teaching and the curricula aimed at deaf pupils. The emphasis (both on practical level and on academic level) is instead on linguistic and cultural perspectives and less on science and conceptual change teaching. The writers note that one of the purposes of deaf education should surely be, as it is among the purposes of general education too, to teach pupils the basic scientific concepts and how to apply them in real live problems. The authors also propose in their article to make conceptual teaching a central approach, which again is essential to this research and its focus on CCT.

8 Many researchers have indicated that D/HH pupils have trouble in reading (see Traxler,2000, Paul, 2009)

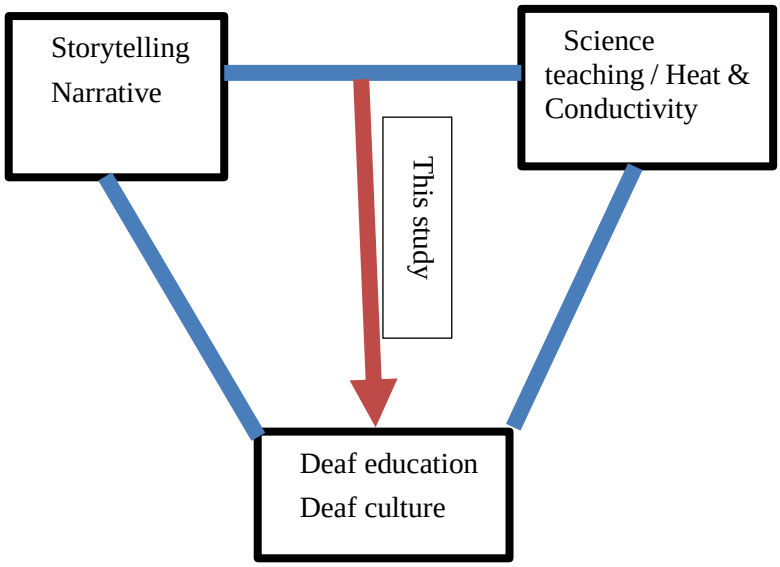
3.4 The gap

Although, as we can see from the literature review, there is a strong connection between storytelling and science, deafness and storytelling and a need for better science teaching in deaf education, there seems to be limited literature when it comes to the connection of the three concepts (storytelling, science literacy and deafness). What this research is trying to accomplish is filling the void in the literature concerning these areas and propose a practical form of planning for teaching science that furthers academic insight on these topics, but that can at the same time be a strong tool for teaching practitioners looking for innovative teaching methods in science class.

More in particular, there is a huge gap when it comes to the chapters of "heat and conductivity" in the Greek national curriculum of deaf. Appendix 1 shows that the Greek curriculum for the Deaf has no goals (neither general nor special) when it comes to the teaching of the chapter of "heat and conductivity". This void is likely to negatively affect the teaching of these concepts. The absence of clear goals is likely to act as an invitation to educators to hop over that chapter. This research provides a specific teaching plan and all the goals needed to teach these concepts in the sixth grade of Greek Deaf schools. The results of the research shed light on the effectiveness of the planning, while the participating teachers provide feedback on how other teachers might use it. This renders the research useful in addressing the two main problems of science teaching in the education of the D/HH: inadequate empirical data present in the literature, and a clear lack of élan and suitable theoretical perspective in teaching science to D/HH pupils.

Finally, the concepts of heat and thermal conductivity were chosen as a special focus due to the fact that the transmission of energy and the concept of energy itself are very vague and abstract. Pupils, deaf or hearing, have difficulties in conceptualizing what is energy and how it is transmitted, since they cannot actually see the process with their bare eyes (Erickson, 1979). It seems timely to identify and test innovative ways of teaching these abstract ideas and adjust to D/HH pupils' characteristics at the same time. The following model shows how the study unites the key attributes into a coherent vision of teaching science concepts to D/HH pupils.

Model that shows where the study is positioned in the literature.



Part two | The research

Chapter 4: Methodological approach

According to social constructivist ideas and epistemologies, knowledge is constructed by each individual. Hence there is not a singular truth shared by all, but instead a diverse concept of reality that is the product of a vast range of human activity; knowledge it is a social creation that does not self-evidently 'exist out there' (Kukla, 2000). It is a human product that is socially and culturally influenced (Ernest, 1999). Knowledge is constructed through the personal meanings that individuals collect through their interactions with others and the environment they live in (Kim, 2001). According to this epistemological stance, learning too is based on the individual meanings that people attribute to different phenomena, and that are influenced by social processes. Learning is not passively received input from external forces, but it is actively shaped by individuals, while continual adjustment occurs on the social level (Driver *et al*., 1994). Learning is therefore the most meaningful when individuals are involved and engaged in social activities (Kim, 2001). It follows from these foundational beliefs that social constructivism foregrounds people's personal stories and individual meanings. Therefore too, a qualitative approach is most suitable in capturing the personal attributes of ideas acquired in the social and cultural context of school.

The research was conducted using the elements of action research. According to K. Lewin (1939 as cited in Gustavsen,2001) action research involves conducting experiments in the field. Action is an expression of the theory, and the results of such research should feed directly back to it; action research is the expression of theory in action (Gustavsen, 2001). According to a social constructivist perspective, action researchers and participants have a special connection; they share a partnership and the research can be conducted with the cooperation of everyone—in this case the teachers, pupils, and headmasters (Lincoln, 2002). The results of action research are dependent on the participants and the people that experience the problem that is under investigation. In a school context, action research is most often conducted by teachers, where they take on the role of the researcher with the purpose of solving a problem. In this particular research, the teaching sessions were conducted by special educators in the deaf schools and not by the researcher, although the researcher is herself a teacher working with D/HH pupils. However, the researcher wrote the research and teaching plans after negotiating them with the teachers and getting familiar with their pupils' level. She also provided all the materials needed for the teaching intervention, and the research instruments needed to make light work (as far as possible) of collecting data in the classrooms. She also analyzed the data, using many insights offered by the educators.

Although the researcher is currently working with D/HH pupils in Sweden, it was decided that the research would be conducted in Greece, with the collaboration of the Greek teachers who work there. That is because of language barriers that prohibit the conduct of such research in the Swedish context. It was deemed more important that the communication, the plans and the working material that the pupils had in the classroom as well as the analysis of the results to be done in the mother language of the researcher. This hopefully also enabled a deep and meaningful analysis and valid results.

4.1 The aim and the research questions

In order to identify the alternative concepts of heat and conductivity present among the pupils (at both the starting and concluding phases of the study) the researcher and the teachers needed to be aware of children's' concepts and if they presented a difference after the application of storytelling in their lessons. Therefore, the first research question used in this study is:

1. Do D/HH pupils understand heat and conductivity differently before and after a teacher-initiated, organized storytelling project about heat and conductivity?

The second question focuses on the results from the teaching intervention to be done inside the class.

2. In their teacher's view, has the story about heat and conductivity helped the D/HH pupils studied
    - To better understand scientific concepts? (In this case "understand" means conceptual change/ improvement)
    - In their motivation to learn more about scientific concepts?
    - In solving a problem-based task involving scientific concepts?

Both these empirical questions are designed to answer the central/main question of the research: does a storytelling-based teaching intervention improve D/HH pupils' scientific understanding of concepts (heat and conductivity)?

4.2 Collection data and process of analysis

The collection of data was accomplished by various methods. In order to identify the D/HH pupils' alternative concepts about heat and thermal conductivity of materials, questionnaires were handed out to the pupils prior to the teaching intervention. After the teaching intervention, post-intervention questionnaires were handed out to the pupils. The sequence of pre- and post-intervention questionnaires helped to establish also whether the teaching intervention had helped the transformation of the alternative concepts of the pupils into more scientific concepts. The questionnaires were distributed by the school teachers. After completion by the pupils they were handed back to the researcher. It is expected that the more scientific concept of heat and conductivity that the story promotes, in combination with the teaching intervention, would be visible in particular in the post-intervention questionnaires, and that the pupils would add explanations in their answers based on using that more scientific concept. Each answer and perception that the pupil documented were mapped onto a list of alternative concepts of the pupils, in order to investigate what perceptions, the pupils derived from their learning experiences.

Prior to the analysis of the questionnaires, all the answers received were entered and sorted into an Excel document. Answers to closed questions were coded numerically. Answers to open questions were translated into English and entered in full. The codes that were chosen was 1 for correct answers, and 0 for wrong answers. The questions that had multiple answers were coded with numbers (1,2,3,4…), with the numbers corresponding to the response-item sequence in the questionnaire. The answers to open questions were categorized according to thematic resemblance, meaning that the answers that shared meaning attributes were put in the same category. The names for the categories were derived from the pupils' own sentences. Then the responses derived from the pre- and post-intervention questionnaires were compared as data in Excel. In reporting the findings, the questions are categorized according to the alternative ideas proposed by the theory. The questions 3, 4, 8 and 9 connect to the explanation of the concept of heat, while the remaining questions connect to the explanation of the concept of thermal conductivity. In the heat explanation part, questions 4 and 8 refer to the alternative concept of heat as two entities, and questions 3 and 9 refer to the alternative concept of connecting heat with the heating source, or with a fluid form. In the thermal conductivity section, questions 5 and 6 refer to the alternative concept about metal as a producer of "coldness", questions 1 and 7 with the alternative concept of woolen fabric being a conductor, while question 6.3 refers to the alternative concept that white or light colors absorb heat.

The questionnaires were also divided according to school and analyzed separately for each school. This was done because the pupils from each school had different pre-existing knowledge and different language levels, thus leading to differences in their answers, both pre- and post-intervention. In addition, since the teaching intervention was carried out by local teachers themselves, the project was of course implemented in different ways in every school, thus further enlarging the likelihood of different answers being given in the post-intervention questionnaires in particular. Therefore, the analysis of the questionnaires was done in two ways:

1. First, the alternative concepts of the pupils were compared to the alternative concepts already known from the literature, in order to assess to what extent, the D/HH pupils' alternative concepts resembled the alternative concepts of pupils in earlier studies; and
2. Second, the data collected pre- and post-intervention were compared in order to identify change (the questionnaires can be found in Appendix 3).

In order to answer the second research question and gain insight into the teacher's experiences of the teaching intervention, interviews were conducted with them. Through in-depth discussions with the teachers that participated, the researcher aimed at a far more holistic picture of the teaching interventions. The interviews with the teachers were done orally in Greek. They were recorded, transcribed and translated into English. The transcribed interview data were analyzed by identifying thematic patterns in the teacher's answers, an exploratory procedure that is common in qualitative research analysis. Observed thematic patterns were sorted and theorized using the CCT framework. A representative table of how the themes created is presented in the Appendix 12.

Although the interviews were coded and sorted according to themes, the categories were not quantified, meaning that I did not investigate or account for the number of times the teachers mentioned a keyword or brought up a theme. Instead, my attempt was to single out noteworthy attributes of the teachers' responses in light of my theoretical frame and the research as we had all experienced it. The themes were therefore only created to set an initial order to vast data, before beginning with the interpretation. Therefore, we can say that the analysis method here is a thematic analysis, but without seeking the objectivity that is often pursued in quantifying results. It is an effort to deal with the complexities of the interpretation of the complexity of human thinking and sense making, including the meaning making of the teachers: the analysis is best considered hermeneutically, as an attempt at deeper and richer understanding.

Due to the various differences that the results present, data analysis was done for every school separately, because every school worked in a different way and the differences in the levels of the pupils, the environment influence and the opinion of the teachers were large. In the end, the main points and conclusions of all the four interviews are presented merely as a general overview of the whole project. The questions that the teachers answered concern their overall opinion on the procedure, what actually happened in the class, their opinion on the educational value of the project, the pupils' motivation during the sessions and the extent to which they think that pupils enhanced their understandings of heat as scientific concept. The interviews followed a semi-structured form, namely questions were structured in advance and the teachers were called to answer to those questions. However, if the researcher felt that the interlocutor presented a difficulty in understanding the question, then additional questions were provided for the facilitation of the process. Furthermore, if the teachers felt that they needed to add more information, then they had the freedom to do so. The questions were divided into three parts: questions about initiating the project, questions about what happened during the project (emphasis on the story, experiments and the final construction) and questions about the end of the project (the questions that the teachers answered can be found in Appendix 4).

4.3 Piloting

During December 2016 and January 2017, a pilot study was planned to test the reliability of the research tools. The original planning involved that the questionnaires would be distributed to the pupils of Kannebäcksskolan (Gothenburg, Sweden) for D/HH pupils, in order to determine if the questions are easily understandable from the pupils and they can easily understand what to write. However, after contacting the school multiple times, I did not manage to execute a pilot in the Swedish deaf school. Nevertheless, a pilot study was initiated using as sample children from other types of schools to give their insights on the structure of the questionnaires. Children from special education school settings, hearing Greek children with the same age as the sample and Deaf adults were asked to evaluate the questionnaires. The choice of these groups was made based on the fact that they share some common characteristics with my sample (same age, curriculum, written language understanding, deafness). The results from the pilot study influenced the current form of the questionnaires.

4.4 Sample

The researcher initiated contact with all the six deaf - bilingual schools in different cities of Greece and Cyprus through emails and phone calls. From the six schools, three of them agreed to participate in the research located in three different cities. The children are between 12-15 years old and they are currently studying in the sixth grade. Our sample is D/HH pupils that are attending primary education because, according to the official curriculum for deaf pupils from the ministry of Education in Greece (as retrieved from http://hdl.handle.net/10795/978), the chapters of heat are taught in these classes. There is variation in the gender (both boys and girls are participating) and a variation in their hearing capabilities (deaf, hard of hearing, pupils with cochlear implants). In one of the classes, the children have basic reading and writing skills. In this case, the plans were adjusted accordingly.

For the better representation of the pupils' skills and capabilities, the researcher requested the teachers to write a paragraph with the characteristics of the pupils. Information such as reading/writing skills, additional learning difficulties, hearing aid and degree of hearing loss were described to facilitate the design of suitable plans and goals that the pupils can achieve. This information served as an additional aid for the better understanding of the pupils' level in order to adjust the planning and the goals that was required for each class. The permission of the parents was requested before sharing this information with the researcher and it was decided to take them into consideration, but not present them in the current essay. The names of the children were not mentioned in the description, only the characteristics of the classroom a whole. The number of pupils participated were in total 17, 8 of which were attending in the school A, 4 in school B and 5 in school C.

The teachers who were interviewed are special education teachers with specialization in deaf studies and fluency in sign language. From these, three were female and one was male, also two of the teachers were hearing, one was deaf and one was hard of hearing. For the conduct of the interview with the deaf teacher, an interpreter was used, whereas the interview with the hard of hearing teacher was conducted by the researcher with the help of the teacher's lip-reading skills and her basic and limited hearing.

4.5 Why these methods? Advantages and limitations

The researcher decided to use questionnaires with the children and interviews with the teachers due to practical problems in using other research methods. The ethical committee for research in school premises forbids any researcher to interrupt the educational practices for more than two hours. Consequently, the researcher cannot conduct the project herself in the classroom as long as she is not an employee at the school. Besides, an important part of the teaching process is the usage of sign language, which the researcher has a very limited knowledge that is not enough to carry a teaching session. Secondly, it is very important for the pupils to feel safe and stress- free during the whole procedure and having lessons with their own teachers was preferred. Therefore, the tools that did not require the researcher using her sign language skills were the questionnaires and the interviews with the hearing teachers.

However, the tools have some limitations. Obviously, it would be preferred if the pupils could provide answers in their mother language instead of their second language (written Greek) because we could get more details about the way they think. Interviews with the pupils in sign language would offer a deeper understanding about their opinions and feelings about the project, but the lack of proficient sign language skills prohibits the implementation of that option. Moreover, the usage of more than one questionnaire would have create more stress and a bigger language burden. Nevertheless, the usage of questionnaires with the pupils and interviews with the teacher can also provide valuable information as we are gaining opinions from both participants (pupils' and teachers' views).

Due to the fact that I analyze the data in a deductive and not in an inductive way, it needs to be noticed that there might be a certain bias in my interpretations as the analysis of the data are not disconnected from the ontological, epistemological and axiological views of the researcher. The researcher supports the idea that the truth is somewhat subjective and a universal reality does not exist especially when we discuss pupils and teachers with different ideas and ideologies. Limitations also existing in the fact that the results were translated from Greek to English, thus creating a linguistic barrier.

4.6 Project relevance

The literature of science literacy for D/HH pupils is very limited and new practices need to implement in order for both pupils and teachers to benefit. This research is a combination of problem-based learning, project and storytelling with scientific ideas and it is an investigation that contributes to the current literature. Studies have shown the connection between literature and learning about science (Hatzigeorgiou, 2006, Kokkotas, Rizaki & Malamitsa,2010) in hearing pupils. It will be very interesting to see if we have the same results in D/HH pupils.

Apart from reducing the void in the literature, this project can be used to change science teaching practices in deaf schools to a more effective method for both teachers and children. It also sheds light on how science is already being taught in Greek deaf schools and it presents a new didactic model for science teaching, combining language development, cooperation and problem solving. This is very important as the teaching design is based in almost all of the general teaching goals proposed by the curriculum for deaf (Appendix 2).

Moreover, the project/plans can be used by other researchers who wish to gather empirical data on the topic in other countries on the same topic or in other teaching contexts by adjusting the plans to suit every occasion (e.g. teaching children with ADHD, autism, blindness.). Furthermore, the plans can be useful for teachers, parents, private tutors and different deaf schools who wish to have a different way of teaching science. The plans and the findings can help curriculum developers when writing new curricula/ textbooks for the deaf on science. The intervention itself is useful primarily for the pupils themselves as it offered an opportunity for enhancement of scientific knowledge.

4.7 Research procedure and didactic tools

The didactic tools that were used for this alternative didactic approach for the concept of heat consisted of a story (the story of Dimitris), worksheets that included the activities which the groups of pupils had to work with during the learning process, the experiments that pupils were asked to conduct and the construction they had to make.

4.7.1 The story

The story that the pupils had to read was the story of Dimitris with the title: “The child who wanted to carry cold water” written by S. Pelasgos and V. Kollia. The choice of this story was made because this story sparks active participation and creatively engages children in reflecting about the concept of heat. Moreover, the text itself leads to various creative activities and introduces efficiently a natural phenomenon that is difficult for children to understand. It gives many and enjoyable metaphors and personifications that in the hands of pupils are a valuable tool to detach them from their alternative ideas about this concept. The original text was written in Greek and translated in English for the purposes of this paper.

It is about a boy that has a similar goal to our pupils. The hero’s goal is to find a way to transfer the cold water from the mountain to his village without letting the water get warm. After several attempts, he decides to stay in the mountain until he finds a solution to his problem. During his wandering, he discovers two magic doors: the door where “Lady Warmth” lives and the door where “Sir Frost” lives. He requests their help, but all they do is to give him one pair of glasses, motivate him to start looking at things in a different way to solve his problem and they provide him with a riddle. After several attempts to solve the riddle, he finds a way to see how the heat is transferred by using the glasses that the characters provided him. By understanding how heat is conducted he finds the solution to his problem and he brings the water cold to his village.

The story serves two purposes. First of all, it helps pupils cognitively as it provides useful information about the transfer of heat and it can provide the pupils with a cognitive image on how heat is transferred to help them with their similar quest. It also provides secret hints what are good and bad conductors and it conveys the message that we need to have an understanding of what is happening at the microscopic/ atomic level in order to solve our problem. Secondly, the story functions as an emotional support for

the children. During the reading, the pupils can see parts of themselves in the hero and they can draw inspiration from him. They are faced with a similar problem and they can read about the hero's strength and persistence, and that works as motivation mechanism for the children. The emotional connection will be reinforced from the in-depth discussions that the teachers initiate with the pupils. The story was divided in three parts in order to give space to pupils to absorb the story and problematize the choices that the hero makes. (The translation of the story can be seen in Appendix 6)

4.7.2 The plans

The experimental procedure was initially calculated to last approximately 10 hours or 5 days (2 hours per day). However, when the time division was decided with the school teacher according to the learning rhythm and specific time needs that each class has, they took significantly longer. The hours were spread within a two-month period and they were hours from lessons of physics, literature, art and project work, thus not preventing the conduct of other lessons during the day. A plan was formed as to what kind of activities they held. The activities of the plan and their level are based on the goals proposed in the Greek curriculum for deaf schools (Appendix 2).

During the teaching intervention- which included 5 teaching sessions- the children worked mainly in groups. Nevertheless, there was no lack of individual activities. At each of the phases of the study, the children participated in various literary activities and activities related to the concepts of heat (activities related to natural sciences).

Literary activities aimed at highlighting and recording the elements of the text, its link with the children's experiences and its creative understanding through their imagination. Thus, the pupils expressed ideas and views for the content of the text, made assumptions and interpreted behaviors, while through questions that were asked by the teacher, they tried to get into the hero's position and to compare his story with the work assigned to them.

Along with the literary activities, the children were also engaged in natural sciences' activities related to the concept of heat and its properties. Thus, in an appropriate pedagogical atmosphere created by the aesthetic enjoyment of the story, the children participated in talks about heat, worked together to complete the construction and conducted experiments.

The main objective of the teaching sessions was the pupils' aesthetic satisfaction of reading the story and through it being interested about creating their own construction. Through the hero's example, pupils had the courage to see another hero to do something similar to them. In addition, it was helpful and a kind of inspiration from which they could obtain information and construct a mental model for heat in order to decompose their alternative ideas. Furthermore, we aimed to realize whether literature would help pupils apply this model to various problems they face in their everyday life. The problem we have assigned to the pupils is directly related to reality and with something they may do in the future, is that we asked them to construct an ice-cream transfer device that would not allow the ice-creams to melt. Such a construction put some concerns to the pupils regarding the materials they would use or how the ice-creams would melt, which they would try to solve via cooperation using research procedures and data that would draw from literature both at a cognitive and an emotional level.

In short, the plan that was decided is:

- Day 1: The educator, together with the headmaster of the school, will pose the problem which is: "During the summer and at the end of the school year, we will have a school party. All the parents will be invited and, as a thank you, the school wants to offer them some ice-cream cones. However, there is no way to carry them without melting! The school is asking the kids to make a "device" that can help us prevent the ice-creams from melting." So, this is the problem that the pupils have to deal with in the whole procedure. The goal is for pupils, during their construction work is to understand the need to look deeper at the heat and conductivity in order to construct an effective device for carrying the ice-creams. The teacher lets the pupils express their ideas about the problem that was posed and he/she documents the pupils' ideas on the board. Then, the lesson starts by introducing the first part of the story and there will be discussion and thinking about the choices that the hero makes. The teacher can pose a question such us "How people kept their food cold in the old days when fridges did not exist?" in order

to invoke deeper discussion. After that the pupils start proposing material based on their current knowledge and start creating a first draft of their construction. The lesson ends with the pupils providing feedback to the teacher.

- Day 2: During the second day the pupils read the second part of the story and they discuss/answer questions/express other ideas, which are documented. Various experiments are proposed to be conducted in order to help the deeper understanding. From the new information that they have, they make changes to their design.
- Day 3: In the third day of the project the pupils take the third part of the story that presents the mental model of the heat transfer. The pupils based on the picture they formed from their engagement with the story, represent different situations of heat transfer (by touching, waves and radiation) with colours or clay. The scientific definitions for conductors/insulators are given. They discuss the findings and adjust their designs accordingly.
- Day 4: In the fourth day, the pupils gather their materials and begin the construction that will keep the ice-creams cold. At the end they present what they have made.
- Day 5: The fifth day is dedicated to exploring which of the constructions that they have built is most effective and solve remaining questions. (The analytical plans can be viewed in Appendix 5)

Due to the fact that the research takes the form of a project, it was suggested that the teacher creates a "project corner" where pupils can bring materials and various information that they have found and that they deem will help their work. Apart from the story, the pupils will have access to various books, the internet and different sources that enhance their understanding. All the materials will be provided by the school, the teacher and the researcher, but the pupils have the liberty to bring their own materials that will help them with their construction. The role of the teacher will be supportive and coordinating the whole procedure and it will diverge from the traditional role as the transmitter of knowledge.

Each school adjusted the plans according to their time limits and the pupils' levels. Therefore, not all the activities were implemented by the schools. For example, depending on the school settings and teaching materials not all the experiments were realized.

4.7.3 The worksheets

For the purposes of this research, worksheets were designed and leveraged (see Appendix 7) for the five lessons. These worksheets were designed to help pupils in their construction. In each lesson, the pupils had an information sheet that included some proposals about the construction, a worksheet for the design of the construction, and they were given potential changes that they might want to make in their construction and their tools based on the new data that emerged every time. Furthermore, in every experiment conducted, there was also an accompanying worksheet, where pupils could document their observations and the conclusions they drew. These worksheets were designed to be helpful for the group. Many of the schools also requested pictures in order to help D/HH pupils to visualize parts of the story or vocabulary that it was unknown to them. Pictures and videos of experiments were also provided.

4.7.4 The experiments

In the first experiment, pupils were asked to put their hands in three bowls containing water of different temperatures. On the right bowl, we add hot water with a kettle, in the central bowl we leave the tap water as it is without any addition, and in the left bowl we add ice cubes and iced water. The pupils put both their hands simultaneously, one in the hot water and the other in the cold one, for about 2 minutes, so that their hands reach the temperature of the water. Afterwards, they put both their hands in the bowl with tap water. Pupils feel that the hand that was placed in the cold water, when it is placed in the lukewarm water feels warm and the hand that was placed in the hot water, when it is placed in the lukewarm water feels cold. The purpose of the experiment is for the pupils to observe how the human body and its parts perceive heat in the lukewarm water, depending on the environment it was in before, and to draw conclusions about whether our senses can measure the absolute temperature of an object. This helps them understand that some objects are not absolutely cold or hot as we think they are, and it is dependent on our own temperature and the environment we are in.

Videos of other experiments were provided as well (included in the plans). It was up to teachers to choose which of the experiments they would like to execute inside the classroom and which they would watch online. The decision of which experiments will be conducted was based also on which educational materials existed in each school and the timeframe that the teachers had at their disposal. After every experiment, it was suggested that the pupils discuss their observations and their conclusions and try to connect them with the final task that they had to do.

4.8 Research tools

4.8.1 Pre-intervention questionnaire

The data about pupils' ideas and perceptions was collected prior to the didactic intervention, using a pre-intervention questionnaire (see Appendix 3). The questionnaire filling-in was individual for everyone, happened in the classroom and lasted about one teaching hour. The teachers provided extra support to the children in sign language and they also used the internet, when they had difficulty in understanding the vocabulary.

The questionnaire contains 9 questions both open-and-close-ended. Every pupil has the possibility to justify their answers for the closed-ended questions. The questions were designed in this way so that we can highlight the pupils' alternative ideas. The form of the questions was assembled in this specific manner in order to have a meaning for the children as they are connected to the task in the teaching sessions. The researcher did not want to create a questionnaire that included questions that were a representation of "cold" physical concepts, but rather embedded to the reality of the children. Furthermore, the multiple-choice questions were limited as we needed pupils to justify their thinking, without having to choose in the binary "right or wrong" way.

One of the limitations that was later highlighted by the teachers was that they wished that the questions had more images and visual aid for the pupils.

4.8.2 Post-intervention questionnaire

After the teaching sessions, pupils had to complete an individual post-intervention questionnaire. The purpose of the final questionnaire (see Appendix 3) was to compare the ideas documented in it with those of the initial questionnaire in order to determine whether the initial ideas of the children had changed (if a conceptual change had been achieved) as a result of teaching. For this reason, the questions in the final questionnaire are the same as those in the initial questionnaire, so that pupils' answers (ideas) can be compared and conclusions drawn.

The researcher decided not to give more questionnaires to the children as she does not want to impose a bigger linguistic burden on the children.

4.8.3 The interview questions

The interview questions were separated into three parts. The interview included questions on ideas before the implementation of the project, on ideas of the teachers during the implementation and opinions after its conduct. After the interviews, the teachers provided feedback on the researcher about the quality of questions and they were free to express opinions that were not included in the questions. During the interviews and according to the teachers' answers, not all the questions were asked, due to the fact that some of them were answered in another question. The researcher did not want to tire teachers' by making there repeat their answers, so some questions were skipped or joined with others. The structure of the interviews follows the semi-structure form as the respondents were freer to express their opinion and the researcher could keep track of the discussion and constrain the respondent in the subject and not let the discussion go outside the limits of the topic.

4.9 Important dates

The preparations for contacting of the schools has already been made from September 2016 and at the 21st of January 2017, the researcher travelled to Greece to meet with the schools in person and prepare the final details before the initiation of the project. At the beginning of January, the researcher prepared the informed consent forms for the children's parents and the teachers were responsible for their distribution before the researcher's arrival. During the visit (21/1-5/2/2017), the researcher received the informed consent forms and distributed the first questionnaires to the children.

From February to the end of March of 2017, the teachers implemented the plans to their class. At the end of March (27/3-3/4), the researcher travelled back to Greece to meet with the teachers again, receive the material (photographs and documents), distribute the post-intervention questionnaires to the pupils and conduct interviews with the teachers. The interviews were conducted 28/3, 30/3 and 31/3 in each school. In the middle of April until the end of May, the researcher transcribed the data from the interviews, translated them and began the analysis.

4.10 Ethical considerations

Since the data was collected in an empirical way, ethical issues concerning the participants should be taken into consideration. The research follows the specific ethical guidelines provided by the Institute of Educational Policies, which is part of the Ministry of Education, Research and Religion in Greece (http://www.iep.edu.gr/index.php/el/). The researcher created an informed consent form for the parents of the children, which they signed for approval and it was based on the guidelines proposed by the Greek Ministry of Education. The informed consent clarified the aims and the process of the research, the expected benefits, the possible risks, the option to withdraw from participating and described how the researcher will secure anonymity of the participants. In the final part, the researcher described that the pupils do not need to write their names and personal details, only answer questions revolving around their ideas in science. The informed consent can be seen in Appendix 8. In the beginning of the interviews, a similar consent was described to the teachers and all of them gave their approval by replying that they agree to terms mentioned. In the interview analysis, the researcher uses acronyms for protecting the names of the participant teachers and pupils, and the names of the schools are replaced by letters that have no relation to the actual names of the schools.

After the transcription of the interviews, the teachers checked the transcripts and confirmed their responses. Following data analysis, the participating teachers were informed about the results. For the pupils who participated and their parents, a one-page summary will be created and circulated to them after the thesis is complete.

The researcher tried to secure a relationship of trust between herself and the participants. Taking into consideration all the challenges in establishing trust at a distance and the complex and uncertain nature of this process, the researcher was honest and clear with the participants from the beginning of the project (Pirrie, MacAllister, & Macleod, 2012). Mutual transparency was the key point in order to achieve a good cooperation with the teachers and schools. Finally, the data will be destroyed after graduation.

4.11 A note on reporting the results

A separate analysis was conducted for every school that participated in the project, as noted in the previous section, due to the fact that every school exhibited different results. The difference in the results between the schools is influenced by the school environment, the levels of the pupils and the didactic actions inside the classroom. The names of the schools are coded as "school A", "School B" and "School C", and the names of the teachers are anonymized. None of the deaf schools are using microphones or sound enhancers in the classrooms. Because the analysis of each case involves the analysis of a substantial amount of data, I have chosen to present each case as a separate chapter. The results for school A are presented in Chapter 5, the results for school B in chapter 6, and the results for school C are reported in Chapter 7.

Chapter 5: Results from school A

5.1 General information about the school

The researcher first contacted the headmaster in the summer of 2016 in order to ask if they were interested in participating in the research. The headmaster forwarded the emails of the two teachers that were responsible for the 6th grade. I initiated contact with the two teachers through e-mails, where they agreed to participate in the research and implement the project in their class. The two teachers were teaching different subjects in the class and only one of them was responsible for teaching science, language and history. Therefore, it was she who implemented the project, as it was more relevant to the subject she was teaching (I will henceforth name her Kate, which is not her real name). I thoroughly described to Kate the procedure. In the beginning, she seemed worried about the application of the project. However, when I visited the school, we discussed how the teaching sessions would be conducted in a more detailed way. After our meeting, she seemed more excited and confident about the whole procedure. She agreed to distribute the informed consents to the parents and after I received the consent, she would gather the questionnaires from the pupils. The questionnaires were interpreted in sign language and the children received support from images on the internet if they had trouble recognizing specific words. The classroom has a smart board that facilitates the conduct of the lessons.

The school is relatively big and it is close to hearing schools in the area. The teachers and the headmaster were very open to the idea of the project. The staff consists of both hearing and deaf teachers.

Special characteristics of the sample:

- The teacher is female with studies in special education. She has good fluency in sign language. She is hearing and a native speaker of Greek. She is responsible for teaching science, language and history in 6th grade.
- The class consists of 8 pupils, of which 2 are girls and 6 are boys. They are aged 12-15. Out of the 8 pupils, 5 wear hearing aids, whereas 3 wear cochlear implants. From the pupils with the hearing aids, 4 wear it systematically, whereas one avoids using it. Out of the pupils with the cochlear implants, one does not wear the processor due to technical damage. According to comments by the teacher, 4 pupils have better perception of the sounds and speech, whereas the other 4 have more serious hearing loss.

All pupils have good competence of sign language, and half of them have excellent competence in using and understanding written language. Out of all the pupils, one pupil has high-functioning autism, one has ADHD, two have limited stimulus and motivation, one has behavioral issues and one has low intelligence, according to the information that the teacher provided.

5.2 Results from the pupils' questionnaires

General information

The pupils were requested to answer a number of questions regarding heat and thermal conduct before and after the teaching sessions. According to the information that the teacher provided, the pupils had discussed in previous lessons the concept of energy, which is playing an important role in teaching the concept of heat. Therefore, the pupils had some pre-existing knowledge about the concept of energy, which is a part of the definition about heat. However, in the questionnaires that they completed, the word "energy" is not mentioned. From the 8 pupils in the class, 7 of them completed the questionnaires.

Ideas about heat (results)

In question three the pupils were requested to find the reasons of why their bottles would get warm. In the pre- intervention questionnaires, 3 answers mentioned "heat", whereas no pupils (0/7) mentioned

anything about thermal conduct. Instead they expressed two types of misconceptions that are obvious in the literature as well. According to the literature (Erickson,1979, Erickson & Tiberghien, 1985), many pupils perceive heat in a fluid state like air, smoke or steam that can be easily transfer from one object to another or can be preserved inside the objects. Indeed 4 answers mentioned that “hot air” or “hotness in the air” is one of the factors that can warm the bottles. This is also obvious by their answers in question nine that they describe heat as “hot air” as well.

The other misconception that the pupils present and comes into accordance with the literature is the connection of heat with a hot object (Wiser & Amin, 2001, Kesidou, & Duit, 1993, Driver, 1985). In this case, 6 of the answers in question three referred to “radiator”, “fire”, “air condition”, “stove” in order to explain heat. Similar answers are observed in question 9 that heat is explained and associated with a hot object. For example:

“Heat is when you take a shower with hot water and make your body warm. If you don't want to feel cold you must go close to the radiator", "Heat is when we light a fire and get warm"

However, in the post-intervention results we observe differences in the way they express themselves about heat. It is interesting that in the question 3, the pupils presented an increase of answers connected to heat (5/8 pupils report the word “heat” and one of them refers them as “girls” from the story) and 3 answers were connected to thermal conduct (they use the word “hands” to describe the transmission of heat with conduct from our body). In the first misconception, we observe a decrease in their answers connected to heat as fluid (both in question 3 and 9) after the teaching and an increase at the description of heat from the mental model of the story (described as “red girls that move”). Although there is a small change in the post-results, the conceptualization of heat is still troubling for the pupils. This is not so surprising, since pupils may sometimes preserve their alternative ideas until adulthood (Lewis, & Linn,1994, Sciarretta, Stilli & Missoni, 1990). As far as the second misconception is concerned (about connecting heat with a hot object), the answers in the question three were reduced to 3 from 6 in the beginning and none of the pupils refers to a hot object as a means to describe heat in question nine.

In the description of heat, some of the pupils use the alternative concept that is proposed by various researchers (Duit & Kesidou, 1988, Erickson, 1979, 1980, Linn & Songer 1991, Viennot 1997, Tiberghien 1980, 1983, Shayer & Wylam 1981, Summers 1983, Watts 1983) and concerns the distinction of heat in two entities: the “hot heat” and the “cold heat”. In question 4, two pupils are talking and one of them expresses an alternative idea about insulation and the other pupil presents that correct way of thinking about heat and insulation. The pupils of our school were supposed to indicate with which opinion agree more. In the pre-results, the majority of the pupils (5/7) agree with the alternative idea that separates hot from cold, recognizes it as two entities and then concludes that the successful insulation can be applied only for one of the two entities. In this choice it is also included the idea that insulators are “working” according to the purpose that they made for (look 2.3.5 above). However, in the results after the teaching, we observe that the majority of the pupils have presented the opposite results (5/7), choosing the scientifically correct opinion of the other child. Although there is a change in pupils’ choices in the second questionnaire, the idea of presenting heat as two entities is very strong and the pupils’ face difficulty in dismiss this idea. For example, in question 9 (both in pre and post results), there are pupils that describe heat as either hot or cold. Some pupils present the idea of heat in the same question as both hot and cold, thus describing the different representations of heat. Although the inclusion of both terms in the definition of heat is more positive that the clear separation of them, the idea of looking heat as two entities still lies strong in pupils.

Ideas about thermal conduct (results)

In the responses to the first and the seventh question in the questionnaire, it is interesting that the pupils in the pre-intervention questionnaires have not chosen the woolen material as an insulator for heat (one out of the seven pupils have chosen it). This is a common misconception that pupils have about wool. According to the literature (Lewis & Linn, 1994), pupils believe that the woolen fabric does not work as an insulator because it produces heat and therefore, it cannot be used as an insulator for bodies of low temperature. It is more obvious also in the third question that two of the pupils wrote woolen fabric as a factor that the water bottles would get warm. However, in the post-intervention questionnaires the woolen fabric is the most popular answer since all of the pupils have chosen it as an

insulator. Also, in the third question in the post-results, there is no mention of the wool as a heating factor. This might be an example of conceptual change as their original opinions dramatically changed after the teaching intervention.

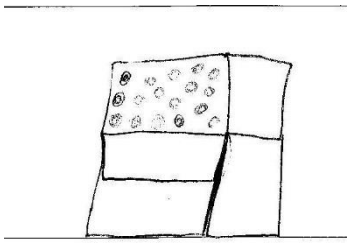
In the fifth question, the pupils were asked to answer which material would serve better as a conductor in order for the toast to get colder faster. Before the teaching, the pupils are divided with half of them choosing the metallic plate, whereas after the teaching almost all of them (6/7) have chosen the right answer. When it comes to metal, Lewis & Linn (1994) report that pupils usually believe that the metallic material is colder naturally, because they attract, hold or absorb coldness or because they conduct heat slower. In this particular case, only two (2/7) of the pupils explained that the metal is a conductor, whereas the rest of the children either supported the idea that the materials were transmitters of coldness (2/7) or gave no explicit answer for their choice (3/7). However, in the post-results almost all of the pupils supported the idea that the metal is a conductor (6/7). This might indicate a change in pupils' way of thinking about metal after the teaching implementation.

Interesting that although almost none of the pupils have chosen the metallic cap and the metallic wire as an insulator in the sixth and seventh question (both before and after), they have however, chosen the aluminum foil as an insulator in the first question. This presents the power that the alternative ideas have on kids thinking. Lewis & Linn (1994) argue that the alternative concepts about the conductivity of metal derive from the examples in daily life. For example, we use aluminum foil to cover cold food in our fridge in order to preserve low temperatures. Thus, pupils' choice to include aluminum foil in the insulators maybe is explained by the power of daily experiences. There is also the possibility that there is a language conflict in this occasion. The words "aluminum foil" do not indicate in any way that it is connected with something metallic, thus the pupils may have faced the difficulty in combining the aluminum material with the metallic one.

Question 6 presents an interesting fact; although the results from the pupils are more or less the same from both the questionnaires, their explanations on 6.2 and their arguments for why they made these choices differ dramatically. As expected the pupils in the pre-results provide answers that are connected to the idea that "the metal is a produce of cold" (referring to their choice of a Thermos flask, 2/7) or they do not provide explanations (5/7). However, in the post-results five of the seven pupils use the mental model that the story promotes in conceptualizing energy and the rest two actually refer to the word "insulator" for describing their choice of a Thermos flask.

As far as the colour in question 6.3 is concerned, there is limited literature that describe pupils' alternative ideas about heat absorption and colours. Most of the literature focuses on heat absorption during its transmission by radiation in pupils in higher education (Nottis *et al*., 2009), whereas other literature sources analyze the misconceptions of the colour in terms of light reflection to our eyes (Matinez-Borreguero *et al*., 2013). From the pupils' answers in the pre-questionnaires, they choose colours of their preference without providing any explanation of their choice (5/7) and some of them connect the colour with an object or experience in order to describe its relation to heat absorption. On the other hand, the post-results indicate a shift in pupils' answers, which they choose light colors and provide explanations not connected to the absorption of heat.

In the second question of the questionnaires, in which the pupils needed to present a drawing of their choices from the first questions, the results were evaluated according to whether they included all the material mentioned in the question 1 and their presentation in terms of details. Some examples are presented below:



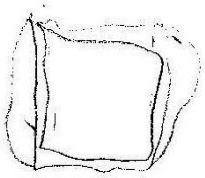
Picture 1[9]

Picture 2[10]

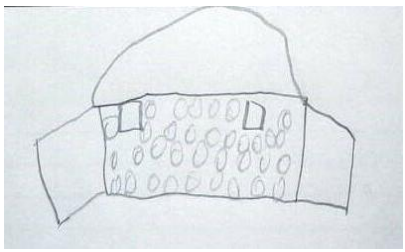
It is evident from the pictures that the pupil has a better understanding of what is asked from her after the teaching intervention. The designs include more details than before and better representation of their imagination. Other examples follow: in the drawings of G, L and M1, there is increased detail in the second drawing relative to the first, in which they seem to have in particular tried to capture the visible attributes of material qualities. The same may perhaps be said of the top-view of the boxes drawn by M2, in which there seems increased attention to the construction of insulating properties.

G:

Before

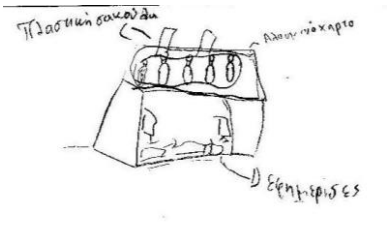


After

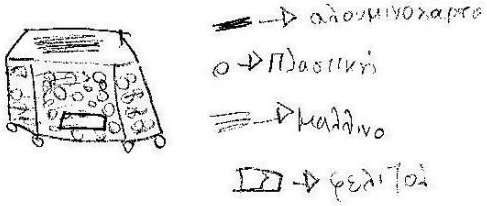


L:

Before



After

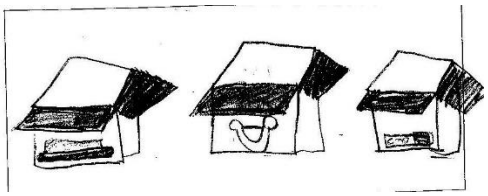


9 Pre-test picture of a girl. She has designed the box with some wire in it.

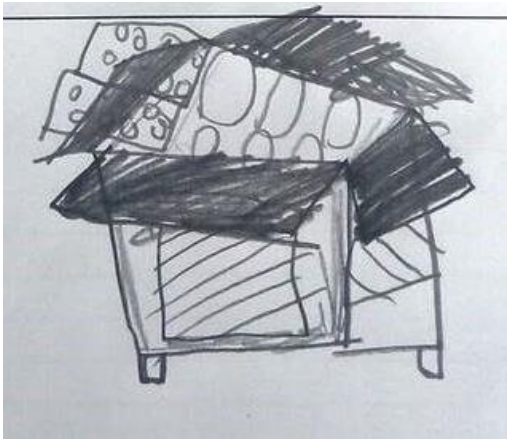
10 Post-test picture of the same girl. She presents the box with more materials, providing a guide on understanding the materials she has designed. Most of the materials are insulators (from top: aluminum foil, woolen fabric, styrofoam, clay, handles, plastic bubble wrap)

M1:

Before

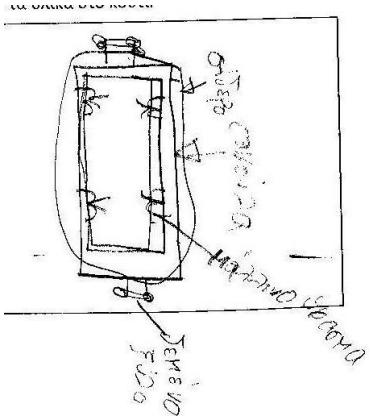


After

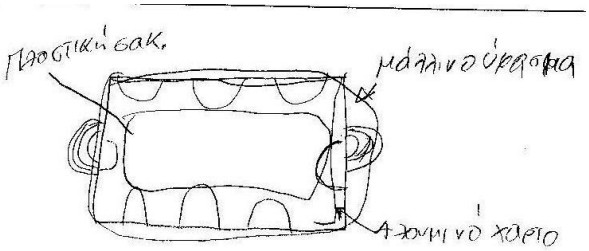


M2:

Before



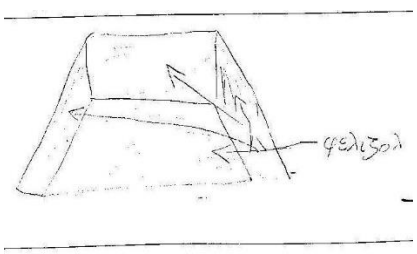
After



A kind of schematic agenda of properties is added by A and L.

A:

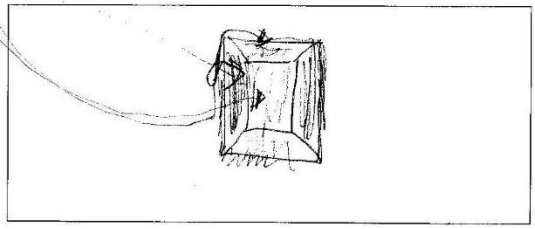
Before



After

Αλουμινόχαρτο	√	
Λεμένο ξύλο		X
Εφημερίδες		X
Μάλλινο ύφασμα	√	
Σύρμα		X
Πλαστική σακούλα	√	
Άλλο.....		

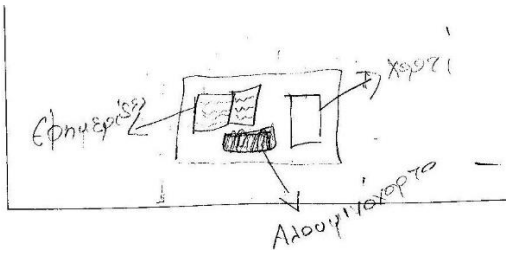
2. Ζωγραφίστε πώς φαντάζεστε να βάλουν τα υλικά στο κουτί.



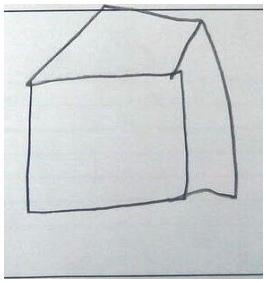
However, in some pupils the second drawing seems less detailed than the first (M3), so the picture task does not present an entirely consistent or unambiguous picture of progress in realizing design details pictorially by the pupils collectively.

M3:

Before



After



The responses to the pictorial questions however increase in relevance when their fit with responses to the other questions is taken into consideration.

Due to the fact that D/HH children feel more comfortable in expressing themselves in forms of pictures rather than written text (Eldredge & Carrigan, 1992), this question was deemed necessary in order to help them express their understandings in a manner that was more accessible to them.

Summary

From the results presented in the questionnaires from School A we observe the existence of alternative ideas in D/HH children on heat and thermal conduct, pretty much as the literature indicates (see Chapter 2). Some of the ideas of heat include the conceptualization of heat in fluid state (see 2.1.1.1), the heat as a "hot object" (see 2.1.1.3) and the representation of heat as two entities (see 2.1.2), whereas in the thermal conduct area pupils present ideas such as "wool as a produce of heat" (see 2.2.1), "metal is cold naturally, so it cools" (see 2.2.2), "insulators work according to purpose (see 2.3.3). After the teaching intervention, there is an increase in children's explanations about the phenomena described and a swift change towards a more scientific way. However, we cannot conclude from the data that there is an ultimate decomposition of these ideas and the replacement of them with a thoroughly scientific way. We can argue however, that there is a positive shift towards a more scientific concept, which can be reinforced.

5.3 Results from the worksheets

This is a small sample on what the pupils write inside the class during the construction project, the experiments and the story analysis. These are evidence that show the procedure of their learning. From the pictures presented in appendix 10, the pupils worked both in oral Greek and sign language. They used pictures from the computer and the help of a projector to process the tasks in the planning (pictures school A, Appendix 10). During the preparation of the constructions, the groups worked using the "construction" worksheet which was provided by the researcher. The pupils have documented the materials in their groups, described the construction in written Greek and, then, made preliminary designs according to information gained from the story and the experiments (pictures school A, Appendix 10). From the experiments proposed, the pupils conducted the experiment with the 3 bowls with water and then discussed the results (pictures school A, Appendix 10). Data from the story analysis is provided by the interview conducted with the teacher.

5.4 Results from the interviews with the teacher

The teacher's perspective

According to the teacher's general impression about the project and their ideas about deaf education in general, the teachers too have formulated certain claims about their pupils' learning and the contribution of the project as a teaching practice. In general, the teacher expresses herself positively about the conduct of the project and its effect on pupil's leaning and motivation. Some examples indicate that:

"I was extremely interested in the project, mainly because of its experiential character"; "The project has multiple benefits. It takes time but it has benefits as well"; "Methodologically speaking, it was complete, it had everything! The interaction, the story, the dramatization, the practical steps."; "Excellent project, I was especially delighted to see the kids come with so much joy and ask for the project to start, which is not the case for the other lessons we have. Even in children with behavioral issues I saw a tremendous change, they got help from the experiments, and learned through play and construction, in this way. I totally recommend it, it was a great experience".

The positive attitude that the teacher has about the project may itself have influenced the processes inside the class and her opinion about the pupils' learning outcomes. Apart from the general impressions of the teacher about the project, she expresses specific ideas about deaf education in general, which present a context of her ideology. In keeping with that ideology and her personal perspective, it is relevant to note her opinions about the motivation of the children and their learning results. Examples of her opinions about deaf education are:

"I think surely if everyone enjoys experiential learning and helps them, here there is one more reason that it helps, because just by giving a book or a text alone to the deaf child, it does not tell them anything. Many times, the motivation to read something is lacking, and we want to reinforce it. They may want more guidance and mobilization on some things. There may be a difficulty in developing the imagination on some issues. But at other levels of production and creativity I did not see any difference [between hearing and deaf children's learning].

We can see a connection between her idea of importance of experience learning in deaf education, and her emotions towards the project. Because she deems experiential learning in deaf education important, she also considers that a project with elements of experiential learning and practical work will have a positive effect on pupils' learning. Taking into consideration the perspective of the teacher, it seems reasonable to note good connection between her views on the effectiveness of the project and the theoretical perspective chosen in this paper.

The teaching process

The planning and the design of the project was based on didactic approaches that the social constructivist model of CCT proposes. According to the model these teaching practices include 5 different phases (see ch. 1.4). The planning included these phases by creating activities such as

a. Introduction of the "ice-cream" problem that was created based on a daily problem they might be faced with, which corresponds to the first phase of the model "Orientation of the pupils".
b. Dialogue for the ideas that they have to solve the problem, question-answers in the analysis of the story, documentation of their ideas in the board, which correspond to the second phase of the model "Projection of pupils' ideas".
c. Conduct of experiments, documentation of their observations, storytelling and literature analysis, dialogue and negotiation in teams, which correspond in the third phase of the model "Introduction of the new knowledge".
d. Application of their observations and conclusions in the construction project, creating the construction, justify their choices in the presentation by referring to the mental model, which corresponds to the fourth phase of the model "Application of the new ideas".
e. Comparison of their ideas before and after either orally or on the white-board and discussion on how they were thinking before and after the project, which corresponds in the fifth phase of the model "Metacognition phase".

According to teacher's report, the plans were adjusted to the children's capabilities and the available timeframe. From the activities proposed in the planning, they have implemented all the activities apart from:

1. They decided to read the whole story in one go and not divide it in the 3 parts proposed in the planning, thus not providing the pupils enough time to assimilate in each part. According to planning after each part there is a struggle from the pupils to build the construction, but they realize that they don't have enough evidence to justify their material choices. This process gives the opportunity to the pupils to understand by themselves the importance of understanding how thermal conduct works and what heat is before they move onto the construction part. According to the teacher they read the whole story continuously and the pupils had only one time to collaborate and exchange ideas about the construction design. According to the teacher: "We decided to read the entire story in one day because the children were so eager to learn what is going to happen. Now I feel that I should have divided it in different parts as the plans were proposing".
2. The exercises on the planning regarding the visual representation of the model (by painting and Play-Doh) were skipped, thus the teaching did not insist on understanding the model in different ways and use it as a tool in the construction part.
3. The ideas were not compared before and after the project as suggested in the last activity.

That indicates that it has been implemented the A, D phases and some parts of the B, C phases that the model proposes, but some other parts of the B, C phases and the phase E was not taught to the children.

Specific details about the teaching practice that the teacher provides in the interview provide us with valuable insights and they are worth mentioning:

"We interpret the story in sign language, we read the text and then we signed at the same time (holistic communication). I asked to see if they have understood, asked them to repeat stuff and I posed questions to see if they have understood."/ "There was difficulty to understand the riddle. We tried to teach it in different ways; to understand firstly what a riddle is and then we used different signs to convey the message properly"

This description informs us about the language processes that the teacher used to convey the meaning of the story to the pupils. These details provide us with a context in order to understand the teacher's ideas about pupils' learning outcomes.

It also seems worthwhile to mention the teacher's description about previous teaching practices in the school in the lesson of physics. This description provides a mental image of how pupils were taught physics in the past and in comparison, to the new teaching process that this thesis proposes.

"We follow one of the two books of the 5th grade for Physics, one is full of theory and many lines and long texts and we have put it aside, and we use the second one that has the images from the experiments, and some small texts, so they do not get too confused. I usually prepare for them, with the help of the internet and some ideas I may have, an "advance organizer", a layout with the basic points of the theory of the course, trying to avoid the very long texts, with diagrams or with few suggestions, so that the exercises we will do, are based on it. We follow the internet too and I have many PowerPoints. I usually bring from my home material/ items such as bowls, volumetric tubes, and batteries to conduct the experiments that the lesson requires."

From the teacher's description we can see that the project was a very different teaching practice from the practices that the teacher and the pupils are used to. This of course, may have influence in pupils' attitudes, motivation and goals. Moreover, the pupils had a very different way of thinking and working with physics before the conduct of the project. It is understood that the teacher was not working with CCT, so probably it is the first time that the pupils work with this model.

In the social constructivist model, the role of the educator plays a significant part in children's learning. Certain characteristics of the educator's role in the classroom are identified by different authors (Leach & Scott, 2003; Mackintosh, 1994; Halkia, 2008). Some of the characteristics are described in the 1.5 chapter of the theoretical section. According to the teacher in this school, her role during the project was as a facilitator of the teaching process and she was responsible to provoke enthusiasm among pupils. She knew the discussed physical concepts very well and she supported the

children both in matters of language (sign language) and in matters of developing the physical concepts. Her role inside the class comes in agreement with the characteristics named from the model in especially the second and the fourth bullet point (see 1.5).

Motivational issues

According to (Pintrich, Marx and Boyle, 1993) motivation and school contextual factors can influence pupils learning and their conceptual change. They propose that motivation and the school environment serve as moderator and mediators of conceptual change. Specifically, when it comes to motivation, Pintrich, Marx and Boyle (1993) suggest that goal orientation, interest and values of importance, efficacy beliefs and control beliefs have an effect on cognitive awareness and facilitation of learning. Sinatra & Mason (2008) also supports the importance of emotions in the learning procedure (see. 1.6 chapter). According to the teacher, the pupils express specific emotions or behaviors that are related to the goal orientation. Specific examples are:

"We had children who really loved this project and they were asking me if we can do it every day, and I had to say, "we cannot do it today, we do not have it in the schedule," They were looking forward to doing it, and some wanted to know when you would even come because they wanted to make it [the box] perfect until you came in order not to feel sad, to please you with the result"

In these specific example, the teacher is describing some pupils in the class that presented an elevated motivation, that we might correlate with mastery/ performance goals. Both from the interview, as well as from private discussions with the teacher, some pupils in the class have a unique interest about science and they are curious about scientific phenomena. This interest might be an indication of mastery goals that the pupils possess. However, in the example presented above, we have a clear indication of performance goal because the pupils were eager to perfect their task in order to get positive feedback in their final presentation.

According to the theory (see 1.6) emotions play a significant role in pupil's cognitive processes, they also influence the augmentation of the situational interest and the value of importance of science. In this specific case, the teacher referred to pupils' behavior and the exhibition of their emotions in the classroom. Specific examples are:

"We didn't read the story in parts as suggested in the plans because the kids were nervous and anxious about what is it going to happen"

In this example the teacher presents two emotions that pupils exhibit in relation to the storytelling: nervousness and anxiety. Although these two emotions are categorized as negative/activating (see 1.6), they can be beneficial for educational purposes. Besides, negative activating emotions can possibly aid the process of conceptual change when they help increase the motivation and focus and, in this context, the teacher mentioned that these emotions lead the teacher and the pupils to read the whole story without dividing it as the planning suggested. In another example the teacher refers to another part of the project and how pupils reacted:

"They loved the experiments, it kept them active from the beginning. They were looking forward (the half-class certainly) when the construction of our main box will start. They couldn't wait!"

The practical part of the experiments and the final construction indicate emotions of enthusiasm and positive activations, which may have a positive effect on conceptual change by increasing motivation, critical thinking and elaboration.

Apart from the emotions and motivation presented from the pupils, the teacher refers to her own motivation. This is very important to be mentioned as the motivation, the interest and the value of importance of the project processes, can play a role in influencing pupils' motivation because they serve as cultivators of the situational interest. According to her views:

"In the beginning, I was certain that they will find it very interesting because it demands from them to do something creative."

From this citation, the teacher presents a confidence and attributes value to the project processes. This can be an indication of transmitting her own enthusiasm and positive attitude to the pupils, thus the

creation of a positive situational interest is more likely. However, she also expressed some initial concerns and motivational opinions about specific parts of the project:

"As far as the story is concerned, in the beginning I was worried that they will get tired or bored because it was long, but in general I thought that the project would invoke undiminished interest because of the construction part."

Although the teacher expresses an initial concern about the length of the story, she also does not lose her positive motivation that the project will help the pupils' learning.

In terms of control beliefs (see chapter 1.6), meaning the sense of control over the outcome of the task and the influence of knowledge, the teacher informs us in different parts of the interviews that pupils took control over how to build the construction and how to use the knowledge from the experiments, the story and the different tasks. A good example on how pupils took control and initiative on building the constructions is:

"They were thinking about it at home and asking their parents for materials. One of our pupils brought us the white pieces of Styrofoam, "because my dad has in his work styrofoam and it will help us." The same pupil, another day, brings some plastic bags, small, airtight and air-filled, because they would also help in our "refrigerator". Another one was thinking in his home the idea with the handles a bit more detailed, how he could work it in school."

This example is also a good indicator of elevated motivation that make pupils think about the school project even outside of the school hours.

Positives and negatives of the project

According to the summarized influential literature in the field (see chapter 1.2), the social constructivist model presents specific positive features, as well as some weaknesses. In the next part, I will try to find differences and similarities to the teacher's opinions about the positives and negatives of the project that is based on the social constructivist model. These ideas that the teacher expresses, influences her perception of the suitability of project to the pupils, thus affecting the statements of pupils' learning. Besides, that analysis can offer an insight on what were the challenges that a teacher had when conducting the project, as well as providing positive and negative aspects of the teaching practice in general.

Positives

The teacher during her interview, focused on the positive sides of the story and the final product. The teacher identifies the linguistic benefits of the story apart from the scientific concepts that included. Some significant examples are:

"The story was had linguistic benefits as well. Even in terms of grammar to see it, it had a number of main and secondary clauses that we could, if we had more time, work, because it is also relative with the curriculum of the 5th [grade], and in the vocabulary level, it helped because we also learned "The salamander" for example that we didn't know, we learned a lot of things"

In this example, the teacher underlines the linguistic benefits that the pupils had on written Greek, namely in the grammatical part and in the vocabulary. However, she also continues by mentioning linguistic benefits in Greek Sign Language.

"The way the story was structured, it helped us presented it in a more theatrical way"

"[Reading stories in the physics lesson] It is more entertaining, and it gives an immediacy to the whole lesson, in contrast with sitting or reading alone, or simply reading and interpreting. Surely this visualization of dramatization adds another dimension to things and helps them to more easily identify with the heroes, especially the children who use only sign language and are not so much based on the written text, were even more identified with the hero, and how he can find a solution to his problem."

In this part the teacher describes that the dramatization that they decided to do inside the class in sign language help the children not only to understand the context of text, but also to identify and emotionally

attach to the hero. In this context, the story not only help pupils in the promotion of scientific thinking, but also in emotional relief of the pupils.

Apart from the linguistic benefits, the teacher mentioned the connection of the story with the daily life:

"A story like this, taken out of life, would help them identify with the hero and understand more things."

This is very significant to mention as many pupils have the idea that science is something difficult and abstract and does not connect with real life. The feeling that learning about physical concepts have an impact on our lives outside the school settings, can also influence the pupil ideas about the "importance of science" (see chapter 1.6). Furthermore, the idea that the story is closely connected to the reality of the children, helps with the emotional connection of the pupils to the hero. That connection can have an impact on pupils focus on the text, on their motivation for presuming the final goal (as the hero did in the story as well) and on their self-efficacy levels (see chapter 1.6).

According to the teacher, there were opportunities during the conduct of the project to train other skills than the scientific concepts discussed. Some examples are:

"When they had to choose the materials [for the construction part] and argument about their choice, it made them think more critically and I think that this is important"

"The image of the girls and the boys, especially when we draw pictures of them and visualized them, it was very helpful. It mostly helped them train their imagination skills."

In these two examples, the teacher considers as positive the fact that the pupils had the opportunity to train their critical thinking and imagination skills. So, in her opinion, the project offered more positive perspectives apart from the scientific part. Her views on the positive sides of the project influence the views that she expresses on pupil learning because she can identify positive aspects that are not connected to the scientific part and they belong to the humanistic side of the project.

Negatives

The teacher in her interview also refers to several challenges and problems. During her description, she mentioned several points that are connected to the challenges mentioned in the literature (see chapter 1.2). In the literature, it is often mentioned that the teachers have difficulties with the social constructivist model because it requires longer teaching time. The teacher comes in accordance with that idea by mentioning:

"I had a small worry that it could take a lot time, because it is quite long and we "miss" supposedly time from the classical physics lessons we teach over"

And

"We need time to interpret properly in sign language in order the kids to understand better."

As is obvious, the challenge of time is one of the weaknesses identified from both the teacher and the SCM.

Another point that it is mentioned as challenging in the literature is that the whole process of the reconstruction of the ideas of the pupils is slow and requires a lot of effort. This has a result the pupils to get tired and the teachers to get disappointed. The teacher presents a similar worry by mentioning:

"I think we still have some difficulties with the physical models and scientific terms and I want still to insist on that. I think that the scientific terms are not full understandable yet. In the explanation / reproduction of the model (with the girls), they showed that they had difficulty. They were replying very simple, mostly about how they felt. I noticed a difficulty in justifying why they put these materials on their box. Of course, I have to admit that some of the kids didn't have the patience to extent their thought in to the next level [the scientific one]."

The reconstruction of the previous ideas, as well as the extension of children's thinking towards the scientific explanations is very difficult to be accomplished especially when the children are not used to working with the conceptual change model in the past. The explanation of the physical concepts of heat and conductivity, require apart from the good understanding of the scientific concepts themselves,

skills such as imagination, critical thinking and strong linguistic skills that allow the right formation of the scientific arguments and justifications. At early ages, it is common for most of the pupils' simplistic ideas to be only partially reconstructed and the complete reconstruction of the ideas will take place at a later stage, when pupils will have developed the necessary skills to accomplish it. The teacher recognizes the difficulties that the pupils had with the model and the scientific terms, as well as the tiredness/impatience that pupils may feel during this procedure that the literature underlines.

Other worries that she expressed are more focused on the didactics of the project and specifically on the story that they had to analyze. These worries are more specific to the project itself and not on the SCM. Some examples are:

"I had worries about the length of the story. It was a fairly long story and many times the kids on the class have no patience when it comes to something so big"

However, later she adds to her worry about the story length:

"The story was easily understandable and indeed it needed to be long in order to covey all the attempts of the hero to transfer the cold water"

She also points out:

"There was also difficulty on how to transfer the riddles of the story in sign language. It could time to construct that part"

In conclusion, most of the worries and challenges that the teacher presents are also connected to the weaknesses mentioned for the SCM in general. The differences between what the teacher said and what it is mentioned on the literature is that she did not mention her educational background and experience with the CCT that the literature underlines and on the other hand she focused on worries on the project itself.

Environmental context

It is important before analyzing the teacher's ideas about the pupil's learning is to understand the context in which the teaching took place. For that reason, it is important to understand the school environment and its condition. The teacher highlighted different problems that influence the teaching:

"I think that first of all there is limited school infrastructure, we should have some more stuff to be able to carry out each time the experiments required by the lesson. Another problem is I think I would like the language that the book uses to be a bit simpler. However, the positive is that we have an interactive board (smart board), I do not consider it a problem, and it helps us very much."

Therefore, in this specific school they had an interactive board that they used during the teaching. That might have also influence the quality of teaching and thus the pupils learning compared to the other schools that ran the same project. On the other hand, we need to take into consideration the big problems with the school infrastructure that the schools have in Greece in general. The lack of personnel, the limited access to a science lab and the right materials for the experiments, as well as the linguistic difficulties of the books often create an unpleasant environment that although it goes beyond the conduct of this project, it still can influence the motivation and the learning outcomes of the pupils.

Pupils' learning according to the teacher

Taking into consideration the didactic practices in the classroom, the school environment, previous didactical practices, children's motivation and pre-existing knowledge, as well as the ideas of the teacher about deaf education in general and their attitude towards the project, the teacher is making specific claims about conceptual change in the children's learning. In her description of the pupil outcomes, she focused on providing examples of the pupils' learning on the story part and on the construction part that are basically the "theoretical- part" of the project and the "practical-part/ final product". She discusses three conceptual areas on heat and thermal conductivity: a. the understanding of the model on the story and the representation of the concept of heat, b. the idea of the transmission of heat by conduct, c. the idea about the conductor "wool".

As far as the first conceptual area is concerned, the teacher discusses if the children achieved the goal we had put for them in the analysis of the story. She mentions:

"They participated [in the story], and understood that there was a connection between language, in the fairy tale, and in physics, that we will see something related to heat, cold, how this child can carry water and preserve it cold. Almost all of the kids understood the image with little boys and girls, and that our goal is the little girls of the heat, to keep them out, to get as little as possible into the box. I think they understood it [the story] very well, and some may have done a comparison with their experience and the hero's experience. I have only a small doubt about two pupils if they have managed to achieve this goal, this result"

In this paragraph, the teacher explains the engagement of the pupils within the story and that according to her opinion, the pupils understood the basic concept of heat transfer represented by "girls and boys". She also mentions the goal that we had set about the emotional support that the story would provide to the pupils. Namely, to see the experience of the hero in the story as similar to their experience with the construction of the box and make parallel efforts to design the box using the hero's observations as support. However, in this school the parallel efforts were not so easy to accomplish as the teacher did not work the story analysis in parts, thus making the comparison harder. Nevertheless, in her opinion the majority of pupils could make this comparison.

In her description, she continues by providing more details on how pupils understood heat transmission by conduct and how the story helped them in their final construction.

"The story helped very much in their construction, especially with the hero's first attempt to carry the water. The fact that the barrel leaned straight on his back… they took it into consideration and they thought (the two groups we were saying) "Oh! Handles, I should not catch it with my hands". They thought at some point the part with the barrel and the back, and they said that the whole base of the box should not touch the floor in order not to get warm from the ground, and they thought of sticking lids off bottles on the base, to lift the construction a little."

The teacher in this part provides an explanation of how the pupils used the knowledge from the story in their final construction and how they began to think practically about the transfer of heat by conduct from their hands or from the ground. She continues:

"The idea of the handles [in the box], before we even discuss it, that a group, "in five" (this is what they were called), considered it before we even begin discussing anything about our hands and the heat transfer, and I was impressed and the way that they tried to think about the handles. Also, the same group impressed me when they thought of putting some "play-doh" on some holes that they opened to put the handles, so the air and the girls of the story would not go inside and affect the ice cream. The other team, "Robocop", had thought about the woolen towel before talking and reminding them of Dimitris' woolen shoes and it was so impressive".

In these two parts, we have a description of how the pupils actively connected the theoretical part of the project and the story with the practical part and the construction. This is very important because one of the main purposes was to explore if the storytelling will not only improve their learning, but also help them apply the knowledge to an everyday problem. According to the teacher, some of the pupils' thoughts on their construction derived from their experience with the story.

Another issue that the teacher focuses on when describing pupils' learning is the idea that most of the pupils have about the wool being a conductor. Apart from the physical concepts, she emphasizes that despite the different problems that created in the process with the team cooperation, as well as the limited resources in the school and the pupils learning difficulties, the pupils got so engaged that she characterizes their opinions as "impressive". In the next example she goes in depth to present a representative image from the classroom by explaining the how one can see the learning occur.

"I thought that every kid was benefit from this project because I saw faces making connections between the parts. I saw such expressions, especially in their faces, lighting up and saying: "Now I understood why Dimitris wore the shoes and cut the bag and yes the wool can help our own box, now I understand why it can help." Also, smiles to this success, and to the third group, the "twin moons", although we had this difficulty of cooperation between the two children, because of the girl's negativity to cooperate, the other little boy, which I generally do not think was quite an observant on things in our

other lessons, I was particularly pleased because he came and told us things and made his own remarks. The day that we complete the construction of the box, he told us: "I have to put this material in the door so the air does not come in" because he had not cut the cardboard well, and generally he had very nice ideas. The girls must not come in because our ice will heat up. Very pleasant to hear that."

She specifically talks about expressions such as smiles and lit up faces and "a-ha" moments during the teaching which she has interpreted as idea alterations. In her example, she discusses about a very special boy that seemed more enthusiastic and focused on his goal despite the conflicts with his partner. The teacher states that she was specifically impressed because he had not presented such behavior (e.g. sharing his thoughts and providing remarks) in the previous lessons in physics. Furthermore, in this example the teacher makes a reference to the idea with the wool and she specifies that the children talked to her about their understanding on how the woolen fabric will help their final construction.

5.5 Conclusions

In general, the teacher was satisfied from the conduct of the project and the results that the pupils presented. When I visited the school in the end of March to collect the questionnaires from the teacher and interview her, the pupils seemed happy about their final constructions and they welcomed me with joy to show me what they had created. The feeling that I received from the pupils was very positive and from the comments that they teacher shares on her interview, it is obvious that she was also satisfied.

More specifically, there is a difference between the pre and post questionnaires that the pupils had to complete. I would claim that this difference can be characterized as improvement because the most of the answers that there is on the post questionnaire are closer to the scientific way of thinking rather than the pre-questionnaires. In the post questionnaires, the reasoning is more concrete and seems to deviate from the answers in the pre-questionnaire. That indicates that the project helped the pupils achieve a certain conceptual change. However, the answers are not exactly the same as the scientific ones, so there is more space for deconstruction of alternative ideas that might occur in higher grades. Nevertheless, according to the definition provided in the theoretical part (see.1.3.2), we can still claim that there is conceptual change from the moment that we have addition to their knowledge (e.g. the addition of new concepts: transmission with conduct, the movement of heat, insulator/conductor) or alteration (e.g. the alteration of wool from conductor to insulator).

As far as the second research question that we posed is concerned, the teacher provides statements about the three subcategories:

- In the conceptual change, the teacher comes in accordance with the pupils' questionnaires on the alteration of the idea about the traits of the wool.
- In motivation, the teacher testifies about elevated interest and positive activating emotions
- In the solution of the problem asked, the teacher speaks positively about the process of the box building and she renders the cooperation and the pupils' ideas as productive.

Chapter 6: Results from school B

6.1 General information about the school

I initiated contact with this school through emails with the headmaster. They wholeheartedly welcomed my proposal for cooperation and within a few days I contacted the teacher responsible for the sixth grade. In the beginning, the teacher was concerned about the whole procedure as well as the timeframe. After we discussed the details over the phone and I forwarded to her the preliminary planning, the story and the timetable, she agreed to participate, conduct the project, collect the questionnaires and the informed consents and provide me with the results to analyze them.

Special characteristics of the sample:

- The teacher is female, has studied on special education and she has fluency in sign language. She is hearing and a native speaker of Greek language. She is responsible for teaching all the subjects of the sixth class, namely language, mathematics and some history.
- The class has 4 pupils of which 1 is a girl and 3 are boys aged 13-14. From the 4 pupils, 3 of them have hearing aids and 1 of them has cochlear implants. From the pupils with hearing aids, 2 of them wear it systematically, whereas one of them has not received it yet due to bureaucratic reasons. Two of the children were born deaf and one of them received a cochlear implant. One of the children has a severe congenital hearing loss, whereas the other child has a contracted medium hearing loss.

According to the teachers' notes, three of the children have almost excellent skills of sign language, whereas one pupil has almost no knowledge of sign language as he started attending in the deaf school last year (2016). Before that, he was homeschooled, but he received no training on sign language. The teacher described that three of the pupils have very good understanding of the written language, whereas the children that started going to the school last year, named A, has a medium understanding and usage of written Greek. From the four pupils, three of them have no other diagnosis. However, A presents extra learning difficulties in spelling, syntax, understanding and writing.

Some further information about the pre-existing knowledge of the pupils was mentioned in the discussion that I had with the teacher during the interview. She underscores that the children have some linguistic difficulties. For example, the pupil with the cochlear device, D, came to the school two and a half years ago at the age of 10 and she did not speak at all. She was only able to say her name. Therefore, within the last couple of years, the fact that she has expanded her knowledge and she is able to express herself and her ideas is an important step. It is reasonable to have all these difficulties in articulation, in writing the words correctly and in organizing words in her mind. D is deaf, so she sometimes faces difficulties with the endings of some words. K has a severe hearing loss, so he does not understand letters with high frequencies and has difficulties in pronouncing certain words. A has had a surgery in his neck, so he has a hoarse voice.

The school consist of a psychologist, a speech therapist, a nurse, the headmaster and 4 different teachers that are responsible for 4 classes. The school is far away from the city center and the pupils come to the school with their parents by car or by taxi services provided by the school.

6.2 Results from the pupils' questionnaires (pre-post)

General information

The pupils were requested to answer a number of questions regarding heat and thermal conduct before and after the teaching sessions. According to the information that the teacher provided, the pupils had never come in contact with the concept of energy or other physical concepts as the teaching is restricted in language, mathematical and historical teaching and lessons. Through this project, the pupils first encountered and analyzed the concept of heat and its transmission as well as the concepts of conductor/insulator. The teacher, inspired from the planning and in order to better support the pupils created worksheets that help the pupils' understanding. Within the teaching sessions, the teacher

employed some necessary concepts in sign language that would help the children enrich their vocabulary and ease the communication process. Some of the new signs that are also presented on the questionnaires in written Greek is “Defense/obstacle” which was used to describe the concepts of “insulators/conductors” and the word “Spread” which they used to describe the relationship of heat and colors and the opposite of “absorption”.

Ideas about heat (results)

As observed in the previous school, here too the pupils make references of “Hot Air” in the question 3 of the post- intervention questionnaires. This is connected with the alternative idea that was mentioned in 2.1.1.1 of this paper that the pupils perceive heat as something fluid like air or smoke. This misconception is also stated by a pupil in question nine, who has written, *“heat is when we blow our hands to get warm in the winter”.* However, answers that indicate heat in a gaseous state are absent from the post- intervention results.

The alternative idea in 2.1.1.3, the theory that refers to the pupils’ tendency to correlate or explain heat using the source, is also present in the results from the pre-intervention questionnaires. In the answers to 3 and 9 two pupils have described heat as the “Sun” which is the source of heat, whereas the other two pupils describe it in connection to their senses. For example, the wrote *"Heat is when I get warm"* and “*Heat is when I have fever".* However, in the post- intervention results there are hardly any references in the source of the heat.

It is interesting that in the pre-intervention results most of the questions are incomplete or with no response, especially the questions that required the pupils to justify their choices. Due to the fact that the pupils had no experience with science in the past, nor they had discussed the problems presented in the questionnaires, it seemed difficult for them to provide sufficient and complete answers in the justification part. There may be many causes of that phenomenon. There might be linguistic reasons, namely the questions were in written Greek and it was difficult for them to express themselves in a written form rather than sign language. On the other hand, there might be psychological reasons, namely due to low confidence or self-efficacy, the pupils were unsure about their answers, so they decided to respond with the phrase “I don’t know” instead of initiating a critical thinking process. However, interviewing the pupils would have provide an answer to the reasons behind the lack of justification in the pre- intervention questionnaires. Interviews with the pupils where not arranged due to practical difficulties.

The post-intervention results on the other hand were impressive compared to the pre- intervention results, as the pupils’ answers are approaching scientific reasoning. In reference to the concept of heat, the pupils abandon all the answers that connected heat to a hot object or heat as a gaseous form and they provide answers connected to the storytelling and the model that was presented to them through the story. More specifically, in question 3all of the pupils refer to the transfer of heat via conduct by referring to it with the phrases *“our body or our hands will warm the water”*. In question 9, they describe heat as *“the girls and the boys”* and *“The heat that goes to the cold. The boy and the girl”* which is clearly influenced from the model in the story and two of the pupils dare to take their thought one step forward by describing heat “The hot moves towards the cold” and “the heat is transferred to the cold”, which is closely connected to the scientific definition of heat. What the children are trying to express here is that heat is the movement of energy from a body with a high temperature to a body with a low temperature, but they do not know yet the word “temperature” so instead they say “from hot to cold”. In this case we might have a conceptual change as we observe a change from answers connected to alternative ideas in the pre-intervention results to answers with more scientific base in the post-intervention results. Although the pupils do not clearly state the scientific explanation that would indicate a total conceptual change, we can still argue that there is a conceptual change. From the definition that we provided above (ch. 1.3), conceptual change can be considered any change in the pupils’ concepts that comes closer to scientific ideas. In this case, the pupils’ results after the teaching session indicated a positive change toward the scientific definition for the heat.

Ideas about thermal conduct (results)

In the first and the seventh questions, the dilemma with the woolen material is presented. It is already known from the theory (ch.2.3.1) that the pupils present difficulty in categorizing the woolen material in the insulators as they usually consider it as a conductor. In contrast with the school A, the pupils in this school have all chosen the woolen material in the first question. However, I consider that the choice of this option is random as in the question seven of the same questionnaire, the pupils seem to disregard the woolen option and in the question 2 the woolen choice is not drawn. In contrast with the pre-intervention results, the pupils' answers in the post-intervention questionnaire in the questions one and seven include the woolen material. The selection of the material in the first question is not random this time as it is verified from the drawings in the question 2. This might indicate a conceptual change in the conceptualization of the wool as an insulator instead of conductor. The analysis on the story that the pupils have performed and the discussion around the hero's choice to use wool to protect his feet from temperature difference in Mr. Frost's and Lady Warmth's houses might have played an important role in change.

There are interesting results from question 5 and more specifically from the reasoning that the pupils gave. Although in this case almost all the pupils (except for one) chose the right answers (with the metal place), none of the pupils provided a sufficient reasoning for choosing this answer. In this case, the pupils did not seem to provide explanations connected with any alternative ideas and instead they just left the question unanswered or just restated the question. However, in the post-intervention results, all of the pupils chose the correct answer and their justification is clearly based on the model provided by the story. Some of the answers include statements such as *"We want the girls to go away from the toast"* and *"We want to repel the girls from the toast to eat it"*. When the pupils write the word "girls", they mean the small red girls that looked like lady Warmth from the story. This is a good example of how the story helped the pupils form a picture of heat and provided a linguistic model to ease the explanation of question 5.

We can observe a similar phenomenon in question 6 where the majority of pupils chose the plastic bottle as a means to transfer cold milk and they provide no justification for that answer. However, after the teaching sessions, the majority of the pupils' choses the Thermos flask and all of them chose the paper box as well. The justifications that they provide are getting close to the concepts of conductor/insulator, but they do not use these exact words yet. Some examples include *"To create an obstacle", "Defense against heat, impedes", "To protect it"*. Words such as "obstacle", "defense", "protect" were new to them both in written Greek and in GSL and it is a very important vocabulary that the pupils learned before they move to the scientific words of conductor/insulator. Some may argue that the choices of plastic may derive from the daily experience, as the cold milk is sold in Greece in plastic bottles or paper boxes. However, the existence of the choice of the Thermos flask in pupils' post-intervention answers might be an indicator of learning and initially understanding the concept of insulation. The theory (see 2.3.2) informs us that most of the pupils consider Thermos flask material as conductor because of the metallic appearance and maybe that is why the pupils did not choose it in the beginning. On the other hand, the obvious augmentation of answers connecting to the Thermos flask, may indicate a change of this alternative idea.

The literature about pupil's alternative ideas informs us that usually the pupils have the idea that the insulators are made either to preserve hotness or "coldness" (ch.2.3.5). This idea is also connected to the alternative idea that distinguishes concept of "heat" in two entities: Hotness and Coldness (ch. 2.1.2). By conceptualizing heat as two entities then pupils come to the conclusion that insulators can protect either one of the entities depending to the purpose that they were made. The questions 4 and 8 from the questionnaire were created to test exactly these ideas. From the results of the pre-intervention questionnaires, we observe that both in question 4 and in question 8 all of the pupils chose the answers that indicate the aforementioned ideas. More specifically three out of four pupils chose to agree with George, who is expressing the idea that a box made to preserve cold bottles cold cannot preserve the hot food hot. The other pupil chose no answer. Similarly, question 8 asks if the materials chosen in question 7 (for the preservation of cold milk) can be used if the milk was hot. In this question almost all the pupils replied "NO". However, the alteration of the pupils' choices is observed in the results from the post-intervention questionnaires. After the teaching, all of the pupils chose the answers to both

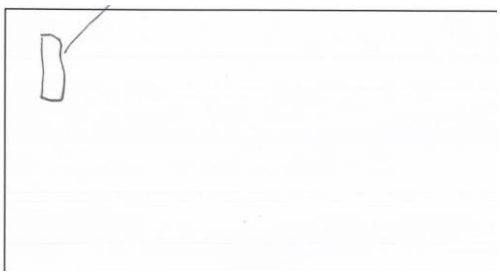
questions that are not connected to the alternative ideas. More specifically, all the pupils in question 4 agree with Anastasia, who expresses the opinion that insulators can preserve both cold bottles and hot food. Similarly, in question 8 all the pupils replied "YES" when asked if the same materials can help the boy carry his milk regardless if it is cold or hot. This alteration of the pupils' answers might be a result of the teaching process.

Finally, there are interesting results from question 6.3 of the questionnaire, where the pupils were asked to choose a color that would help better preserve the low temperature of the boy's milk and justify in what way the color is connected to heat. In the pre-intervention questionnaires, none of the pupils provided an answer to this question and they all decided to leave it blank. However, after the teaching sessions, we observe that the pupils have chosen light colors and as their justification they wrote *"We want light colour to spread the girls"*. The word "spread" was a new word that they practiced in both written Greek and GSL and they used it as an antonym to the word "absorb". The word "girls" that is used in the justification is referred to the model used in the story to describe the movement of heat. Therefore, in that sense, the pupils use the phrase "spread the girls" in order to express the scientific idea that the light colors do not absorb heat so easily as dark colours. This is a very important difference as we observe that on the one hand the pupils could not express their thought about the characteristics of color and on the other hand, after the project, they enriched their vocabulary that thought in order to be able to express the connection between color and heat.

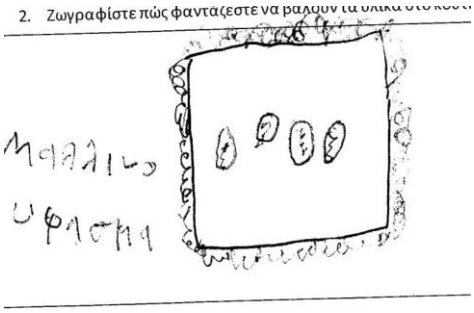
In the second question, the pupils were asked to design a picture of how they imagine the materials that they chose in the first question. This question was designed in order to see the pupils' understanding of the first question. From their drawings, all of the pupils have added visible details after the teaching sessions compared to their designs in the pre-test.

A:

Before



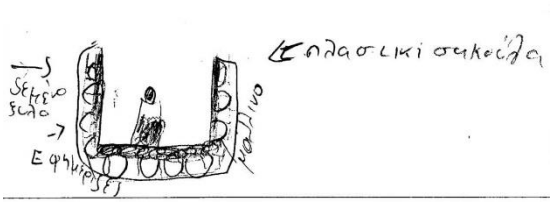
After



D:

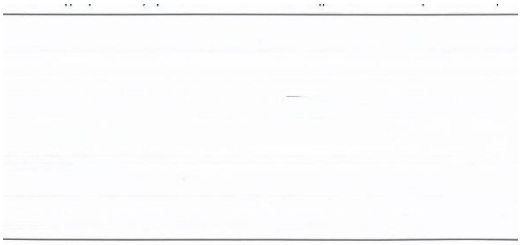
Before

After



K1:

Before



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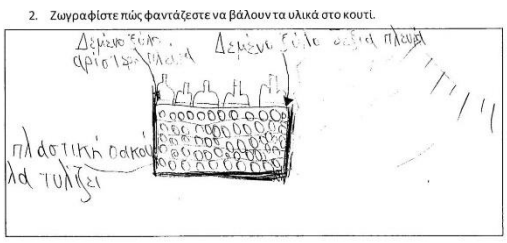
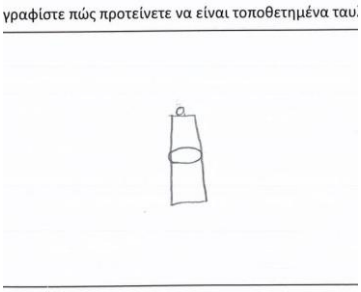
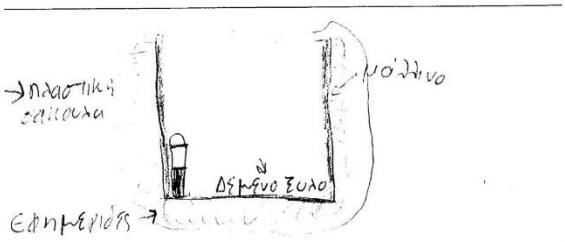


K2:

Before



After



Summary

Summarizing the results from the questionnaires, we can observe a positive change after the teaching compared before the project. Specifically, in the questions that concerned the conceptualization of heat (Q 3,9) two alternative ideas were expressed in the results from the pre-intervention questionnaires: 1. The idea that heat exists in a fluid state like air or gas and 2. The description of heat in connection to a hot object or the source (see ch.2.1.1). However, in the post-intervention results the two ideas were not mentioned and on the contrary, they were replaced by attempts to explain heat with ideas that are close to the scientific definition in combination with the model provided from the story that they studied. This is an indication of a positive conceptual change in the area of conceptualizing about heat that was influenced by various elements of the model in the story.

In the area of thermal conduct, we can also observe positive conceptual change. More specifically, in questions 1,2,7 in the pre-intervention questionnaires the pupils express the alternative idea discussed in 2.2.1 about the conceptualization of wool and its insulation traits. However, the results in the post-intervention questionnaire indicate a change in the pupil's conceptual ideas about wool as a conductor and they prefer the material as an insulator. Furthermore, the idea that was discussed in 2.2.3, that the pupils tend to believe that the material preserve "coldness" or "hotness" according to the purpose that they were made for, is observed in the questions 4,8. On the contrary, the post-intervention questionnaires indicate an alteration of that idea, with the pupils choosing the answers that are close to the scientific way of thinking.

It is interesting that in the questions 5,6,6.3 the pupils justify their answers by using elements of the model of the transfer of heat as presented in the story. Together with the model, the pupils use the new vocabulary that was taught to them in GSL during the teaching sessions in order to be aid in explaining the scientific phenomena.

6.3 Results from the worksheets

Every school adjusted the planning and presentation in a specific way according to the pupils need. In this school, most of the activities followed the planning. However, small adjustments were made by

the teacher in order for pupils to have a better understanding. First of all, in the storytelling process, the teacher decided to teach the story in six parts instead of three. That was because, as she informed me, she thought that the pupils needed more time specifically to understand the language that was used. They performed the analysis of the story by following the recommended questions in the plan. The only difference is that in this case the teacher decided to give the story and the questions in written form to the pupils and they answered them both in GSL and written Greek. She replaced words that were difficult to understand, for example, the word mother became mom and she replaced the past tense of verbs with the present tense. From the notes on the story, they seem to deepen in understanding of the language of the story and they discussed difficult vocabulary and phrases that were unknown to the pupils.

Apart from the answers in the literature questions that were connected with empathy and problematizing on the characters of the story, the teacher documented the alternative ideas of the pupils about thermal conduct and heat in every part in order to become aware of their ideas. This technique is connected to the second part of the proposed theory teaching method that is called "projection of the pupils' ideas". Part of the story process was also the time placement of the story, thus many of the answers of the pupils were the result of discussions on the period of time in which the story took place. This helped pupils make a distinction between how they would solve the hero's problem today and how they would have in the stories time period without the help of technology. Pictures that present the story analysis, the questions and the pupils' answers can be found in Appendix 7

From the proposed experiments in the planning, the class had the opportunity to conduct there of them and the rest were watched from videos on the internet. Pictures of the experiments can be found on the Appendix 10.

It is interesting that in this school they used painting as a didactic tool. Every pupil drew on the one half of the paper a situation where a person had a problem due to high or low temperatures. For example, they drew a person that did not want his cold water to become warm because of the sun or his warm milk to become cold because of cold weather. On the other half of the paper, they drew a solution to the problem by using an insulator. For example, they glued a small piece of wool in the bottle with the cold water and or a piece of wood in the bottle with the warm milk. This was a more visual representation of how we can use insulators in everyday life.

Furthermore, the teacher worked with the theory of thermal conduct by categorizing different materials as conductors and insulator and presenting them to the pupils with the help of pictures. Finally, in the building of the final product, the teacher documented the whole process and discussed it with the pupils to give them space to reflect on their choices. Examples of how she worked with the theory and the documentation can be found on the Appendix 7.

6.4 Results from the interviews with the teachers

The teacher's perspective

As mentioned in the analysis of the previous interview, the teachers support a specific ideology that provides them the lenses through which they see the outcomes of the project. Parts of this ideology is the ideas they express about deaf education in general, as well as their first impressions of the project. The idea that they have about the project creates a predisposition that influences their claims about pupil learning. For that reason, it is important to present the teacher's general idea about deaf education and the project in general.

The teacher in the beginning of the interview, referred to the first impression that she had before conducting the project in her class. She mentions that in the beginning she felt anxious because she was wondering how the pupils would understand the concept of heat and how she could teach physics effectively in deaf pupils. However, after the explanation that I provided to her, that the project had to do with a story and that through this, the children would understand the concept of heat, then she felt relaxed and it seemed something that she can accomplish. The anxiety that the teacher felt in the beginning is understandable as it a new area that the teacher needed to invest in. However, it was

positive that through the right explanations and guidance, she was more confident about the whole process.

Her general comments about the project include positive emotions about the plans, she characterized them as "well-structured" and she thought that it would be a great opportunity for children to learn about this part of physics, as the subject of physics is not taught in this school. Furthermore, she comments that the project generally was very helpful and it helped the kids to understand in a simple way the concept of heat. She even said that she is willing to teach again another concept of physics through story if we prepare it.

Some of the general ideas about deaf education that arose during the conversation with the teacher included references to her perception about how deaf pupils function and learn. In her opinion, deaf children need a more experiential way of teaching than hearing children do. For example, regarding the difficult concepts of physics, she deems that she cannot just describe the concepts to them or read scientific definitions on a text. They need to understand how to use these concepts and how the whole concept of articulation works. She claims that for hearing children, the lesson about the heat concept might end in one day. For deaf children, a textbook unit can take a week in order to make sure they have understood the vocabulary and the specific language that is used. She provides an example by saying that it is easier to say to a hearing child "metal is a good heat conductor" and there is a chance that the child will automatically understand the meaning and be able to remember it. For deaf children, physics is connected to language teaching and even teaching of basic scientific concepts that hearing children might have heard before from their environment. In that way, physics take a language teaching orientation rather than a conceptual one.

As far as the imagination skills that a deaf pupil has, she mentions that deafness can affect the development of imagination and abstract thinking, as they are both closely connected to it. If she does not explain some things to a deaf child that a hearing child has already known, they will not understand them. For example, a hearing child will hear something and will process it. A deaf child, if he/she does not see or picture a concept or a word in general, then they will not understand it. So, we have to tell them, explain it to them, and then they might succeed and cultivate their imagination even better.

The teaching process

The planning and the design of the project was based on didactic approaches that the social constructivist model of CCT proposes. According the model, these teaching practices include 5 different phases (see ch. 1.4). Activities based on the phases were created in the planning and the specific correspondence was described in the results of the previous interview (see ch. 5.4/ Teaching process). According to teachers report, the plans were adjusted to the children's capabilities and the available timeframe. From the activities proposed by the planning, they have implemented the almost all the activities proposed from the planning. The adjustments that she made were the following:

1. She introduced the project to the pupils by having simplified the text in the beginning, in order to teach it faster. It took them about a month to finish the story because she was teaching it in small pieces together with the corresponding questions that were suggested in the planning. She made the story more concise and she slightly simplified the sentences based on the level of her pupils.
2. They did not watch the videos, but they performed the all experiments proposed. The pupils conducted one experiment extra in order to understand and explain the transfer of heat through conduct.
3. The discussions that were suggested by the planning occurred as follows: She asked them in sign language to justify their choices in the construction, they responded in sign language, and then they should tell me, if they could, in spoken language. The discussions between the pupils in their groups occurred using GSL.
4. The ideas were not compared before and after the project as suggested in the last activity.
5. In the story analysis, the teacher projected the pupils' ideas in almost every part of the story that they analyzed.

That indicates that the phases A, B, C, D were implemented, but the phase E did not occur.

It is also necessary to mention previous teaching practices in the school in the lesson of physics. The teacher informs us that they do not teach the subject of physics at the school, but they focus more on the subjects of Greek language, mathematics, history, so this project was a great opportunity to introduce physics into the school's schedule. Due to limited time, pupils were not much engaged in physics in previous years.

Motivational issues

In our discussion with the teacher about the motivation that the pupils she expresses very positive and activating feelings towards the problem that was posed to the children, the story and the final construction. More specifically the teacher informs us:

"The kids reacted to the problem by having the urge to see how we would do it. They were thinking about it themselves during the story, because we did it in parts, and they were making hypotheses of what was going to happen next"

In this part we can see that the pupils present a situational interest that created by the problem and the story that the teacher provided to them. That is very significant as we already have argued that the situational interest may lead to increase in personal interest and high self-esteem when it comes to learning about science (see ch. 1.6.2). Emotions such as urges, surprise, choice and fantasy can lead to a situational interest about the concepts discussed. An increase in personal or situational interest can ease the conceptual change process. In another part the teacher, when asked to comment the motivation of the pupils in the whole project, she says:

"They liked the project very much and they were extremely excited about the construction. When the story finished, they seemed to love it. These reactions could easily be seen, because they were smiling and were making big gestures"

Emotions such as "extremely excited"," like" and "love" are positive and activating. As we have already explored (see ch. 1.6.3), positive activating feelings can initiate action and critical thinking as well as they can have positive effects on pupils' self-efficacy (see ch.1.6.4) because they feel that they can complete the task and find solution to the problem that they had. The teacher describes how they exhibited their enthusiasm through smiling and moving their hands in a more expressive way.

During the interview the teacher also referred to the freedom that the project provided to the pupils. She informs us that the pupils could make their own choices, think critically about them and have control of what they were doing. This statement is connected to the importance of control belief in ease the process of conceptual change (see ch. 1.6.5). The pupils had the control over the outcome of their construction and that helped them with their confidence and in the sense that they can achieve their goals.

Positives and negatives of the project

Positives

During the interview, the teacher mentioned what were, according to her opinion, the positives with the project. From all the activities that the pupils did, the teacher decided to focus on the storytelling and its analysis inside the class. She explains her own emotions about the story first that seem to be positive and activating:

"I liked the plot very much. I was excited from the fact that it went to the source the first time, the second time it went with the metal barrel, which was heated by the sun, and the third time it finally found the solution. Eventually, it showed us the wrong way with the metal barrel and then the correct one. Similarly, my pupils would face the same difficulties with their own construction. First, their choices in the construction were not as effective compared to the problem they were facing. Like the hero in the story, they would try again, experiment, look for more information and then try again until they succeed. It was a parallel journey for us."

The teacher expresses the connection between the task of the hero (to carry the water cold) and the task of the children (to carry the cold ice-creams without melting). She refers to the fact that the story not only connected to the pupils' reality by providing a mental model about heat, but also it provided

an emotional connection as the actions of the hero were closely connected with the actions of the children. In the word of the teacher, the story and the kids were working in parallel.

In our discussion, the teacher commented on the mental model that the story presented about heat and heat conduct. She mentions that the mental model made the whole procedure much easier and it gave the children a common base to communicate. More specifically, she presents examples of the model was used:

"The model with the boys and the girls made the life of my pupils easier. I explained it to them with examples such as: "This is warm, so what does it include? Girls. What do we want? We want them to enter or leave. So, I was explaining the movement between them."

She attributes the characterization of mental painting in her description about the mental model of the story. She specifically mentions that she believes that it was like an image, a picture of this story and especially in the part in the river when he wore his glasses and he saw the little girls enter (first picture) or the boys come out to the surface of the water (second image). Therefore, she deems that the pupils could automatically paint that moment with their minds and she think that this paragraph itself was the whole essence of the story. "It was like a painting," she claims. She continues by connecting her argument about the mental painting to the pupil's imagination skills. She claims that it was more helpful that the story was not illustrated because the pupils become focused on the pictures and they do not allow their imagination to be cultivated. Thus, she supports that the fact that the story did not include pictures made the pupils think by themselves and process the information in a more creative way. For example, she says:

"The concept with the heat and the glasses was better that did not include picture, because then the kids had to paint the red and the blue with their minds and show where the heat and the cold came from, so it helped the cultivation of the pupils' imagination. It was also an easy picture to be painted, because it seemed very easy through the story who enters and who comes out".

Linguistically, the teacher found the fairy tale more helpful than the textbook, because the concept is introduced very simply and the scientific terms are not included. She continues by saying that the words of the story were fairly easy, and they were not really difficult, thus she used the text from the story to teach the language lesson of the day and to introduce new vocabulary. Generally, she refers to the concepts as simplified and that is very important for the deaf pupils due to the difficulties they face with written language.

As positive, she recognized the fact that the text was not only offered for language analysis, but also for literature analysis. She liked the questions that were given in the plans because through them, she could have a deeper analysis of the story and push her pupils think more critically. The questions were the means for a more esthetic and empathetic understanding of the text.

In general, she considered that the pupils would not have trouble understanding the story because it was given in an uncomplicated way. She believed that the pupils enjoyed the project very much, because the lessons became experiential. In that way, they would remember more easily the facts, for example what materials they used the knowledge they got from the story. The lesson was successful in her opinion, because both the story and the construction helped the children to extend their knowledge.

Negatives

In our discussion, she did not mention any specific negative about the project. We discussed the fact that it took more time than originally expected but she commented that although the story may take much longer, it was worth it, because it was getting more understandable by the pupils. Sometimes, the time was wasted on language analysis. She specifically mentions:

"For deaf children, we have to check if they remember the words. As you saw inside the classroom, they could make the signs correctly but they confused the words. They did the correct sign, but they could not correctly remember the word in order to write it. Therefore, we are a bit late to match the sign with the word, because it is a new vocabulary for the deaf children. It is not like the hearing children who have heard the words. Deaf children are now learning these words because the written language is their second language"

Pupils' learning according to the teacher

The teacher commented on the pupils learning according to her own understanding from the behavior inside the class, the completion of the learning outcomes and their answers in the final presentation and teacher's questions. One of the most important learning outcomes that the teacher noticed and it is also obvious in the analysis of the questionnaires is the understanding of the woolen material. It is noticeable in both the literature and the teacher's observations that the pupils, before the conduct of the project, believed that wooden material is an insulator or "heat producer". However, after the project the pupils seem to have shifted in that misconception as the teacher testifies. For example, the teacher informs that it was because of the story that the pupils changed that misconception:

"Every pupil wanted to choose the woolen fabric as their primary material, according to the story, and they said: "We will put this because it is woolen. Also, the pupils justified the reason of choosing the woolen fabric because they had understood it completely through the story. They justified the reason of choosing the other materials, as I explained before about the good and the bad conductors through an extra lesson that I had".

The fact that the pupils at the end of the lessons were able to clearly argue their choice of the materials, suggests a deeper understanding of the concepts discussed. In her examples about how the pupils were justifying their choices, the teacher mentions that many pupils used the mental model or scenes taken from the story. For example:

"Another example from the story was: With what did Dimitris dress the sack with? With wooden fabric. So, the carpet is a woolen cloth and we will use this in our box to keep the girls away from our box (the carpet was one of the materials that they had to choose from)."

Another example is:

"They said that we wanted to put the ice creams inside, so when we wrapped the box up, we would prevent the little girls from getting in, so the little boys would be left inside the box"

It is important to highlight the fact that many of the pupils deal with linguistic problems, thus their effort to justify their ideas in a presentation in front of their classmates is a big accomplishment. Of course, they were some kids that gave more answers than others did because they had better linguistic skills. According to the teacher, a child who is hard of hearing, answered to the teacher's questions with more details in the oral speech, rather than the deaf children or than the child with the cochlear device did. For example, the child with the cochlear device has now learned the words that they analyzed through the story. Other pupils decide to describe their thinking in sign language although many of the signs are new to them. For example, they practice new signs like "defense, obstacle, absorb, spread" that the pupils were not familiar with before.

Very important to the teaching process was conducting the experiments, as the teacher points out. The pupils seemed very excited especially during experiments that were more experiential and when they understood that wood was a bad conductor. Especially during the experiment with the briquette, the spoon and the wooden stick, they began to realize the good and the bad conductors. That helped them in their construction as well. For example, one of the materials they had to choose from was sheets made from cork. Since they assumed that cork was made of wood and they saw from the experiment that wood is a bad conductor, what were they supposed to dress their box with? With cork. Moreover, as the teacher attests during the experiment, when they put one hand in the cold and the other in the warm, when they put both hands in at the same time, their eyes widened and they said: "I cannot believe how that happened!" It is thus important to highlight that the pupils noticed connections between parts; the way information from the story, the experiments and their activities were connected to their final choices in their constructions.

As far as the pupil's difficulties with the concept of heat is concerned, the teacher claims that the pupils understood heat and a catalytic role in this is played by the mental model provided from the story. For example, she mentions:

"The project was very helpful and it helped the kids to understand in a simple way the concept of heat. Moreover, through the given material of the project, pupils comprehended better these concepts.

For example, when we wrap the box up, what does the heat do? Is it inside? If not, where does the heat come from then? How do the girls move when we have conduct?"

The teacher also attests that the pupils could take their knowledge one step further and understand that the heat transfers from a hot object to a cold one which is very close to the scientific definition of heat. That can be also confirmed from the definitions of heat that the pupils give in their questionnaires.

6.5 Conclusions

From the analysis both the pupils' questionnaires and the teacher's interview, we observe that there are two alternative ideas that the pupils managed to change. One of them is the misconception connected to the woolen fabric, which the pupils believed in the beginning that it is a conductor or "producer of heat", whereas at the end of the intervention the results show that the pupils consider it as an insulator and they are using it in their construction. Secondly, the conceptualization of heat has changed. From the teacher's testimony and from evidence in the last question of the questionnaire, the pupils seem to define heat as the process of energy transfer from a hot object to a colder one, which is close to the scientific definition. This is very important achievement if we take into consideration the various linguistic problems that the pupils deal with and their unfamiliarity with the term "Temperature". In their explanations about heat, the pupils seem to use more often the mental model presented in the story and from the teacher's description, the mental model help the pupils better understand and formulate their thinking around the concept of heat. It played also an important linguistic role as it served as a tool of communicating their ideas to their classmates.

More specifically and taking into consideration the research questions that we posed, the teacher evaluated the process as a success and there is a connection between the story and the alteration of the pupil's misconceptions. In terms of motivation, the project played also an important role because it created positive and activating emotions. The final construction was evaluated by the teacher as catalytic activity in pupils' learning and their motivation. Connecting theoretical ideas from the story with practical problems of the pupil's daily lives was beneficial for the pupils in the second school of this research.

Chapter 7: Results from school C

7.1 General information about the school

The first initial communication with the school was conducted through an e-mail exchange with the principal of the deaf school. The principal was eager to conduct the program in the high grades of the school, thus she gave me the two e-mail addresses of the two class teachers working with the fifth and sixth grade. One of the teachers is male and Deaf, whereas the other teacher is female and hard of hearing. The deaf teacher was working with three pupils that are totally deaf who can neither write nor read in Greek, they can only sign, and the female teacher was working with four pupils that were half deaf. They both proficient in sign language, since it's their mother tongue and they can both lip-read.

The biggest part of my communication was done with the male teacher through message exchange via Facebook. I only met the female teacher when I arrived at the school. The male teacher agreed to conduct the project in both classes, combining the pupils from both his class and his colleague's class. Therefore, there were seven pupils in total that participated in the project. In the beginning of the conversation, the teacher did not provide me with much information regarding the educational status of pupils in the class. He insisted that we meet in person and then discuss the details of the project. However, I had previously e-mailed both him and the other teacher with the teaching plans and the story in order for them to have time and read them. The first appointment was scheduled at the end of January 2017, so I flew to Greece in order to find them and discuss further their comments on the plans.

The school is located in a prestigious, but a distant area from the city center and there were no other schools surrounding it apart from the D/HH high school and the deaf community. The building was very old with inappropriate school support for the pupils. Pupils from various areas attend the school and they have access to it through a school bus that is provided. The school, apart from an educational institution, is also a boarding school and some of the pupils are living in adjacent rooms next to the school building. The staff consists of both hearing, hard of hearing and deaf teachers.

In the meeting with the two teachers in the school before the conduct of the project, I was informed that the pupils presented many difficulties, especially in their fantasy and linguistic skills. My impression from our discussions was that both teachers had very low expectations of the children. They do not teach physics at all in the school because, as one of teachers stated, the children have difficulties with critical and abstract thinking, they have limited vocabulary and they have memory problems. One of the teachers was more optimistic about the children's learning from the story and the activities. Nevertheless, the teachers agreed to try out the project. They requested an extension of its implementation until the end of March (instead the end of February) and they asked me to rewrite the story and minimize it in 7-8 pages instead of 10. Also, they told me to replace difficult words with very simple ones in order for the pupils to be able to understand it. They also wanted to reduce the questions in the planning and take out some of the activities. The new plans that I made for them can be seen in Appendix 5. Moreover, they fully supported the idea of having videos and images, so they asked me to add more of them. Furthermore, due to the fact that the children cannot read, we agreed that the teachers will record themselves signing the story in every lesson and present that to the pupils. As I understood, they would divide the story in four parts instead of three and they would work two hours per week for the project because they do not have more time for that and they run other projects at the same time. We agreed to meet them again for the interviews on the 27th of March and I booked an interpreter to ease the interview process with the deaf teacher.

In our second meeting, we discussed the conduct of the project and the teachers expected me to explain the plans to them, but unfortunately, they had not read them when I first sent them through e-mail. It was very difficult to me to explain the whole plans and the story to them since my sign language skills are not very proficient. Therefore, I suggested them to read them before the conduct of the experiment and e-mail me if they had further questions upon it.

Main characteristics of the sample:

There are 6 pupils in total in the classroom, 3 of which are girls and 3 are boys. The age of the pupils varies between 11 and 15 years old. Four of the pupils have heavy hearing loss, one of them is hard of hearing and the other is hearing. From the pupils, three of them have cochlear implants and especially one child has in both ears, whereas the other two have only on one side. The hard of hearing child uses hearing aids and two of the pupils do not have any hearing support. From the two pupils that do not have hearing support, one is hearing and the other is almost deaf. According to the teachers three of the pupils in the class understand and use in a very good level sign language, whereas the other three present difficulties in both understanding and using. As far as the understanding of written Greek, two of the pupils have a good understanding and usage of written Greek, whereas the rest of the pupils have very low/hardly any understanding. According to the information that the teachers provided, five out of six pupils present extra learning difficulties. Three of them have a problem with language, especially they present a lack of vocabulary and the vocabulary that they are using is in basic level. One of the pupil presents behavioral problems, one has difficulties with the Greek language in general as he is new to the country, one has difficulties in understanding and communicating with the others and one has no knowledge of sign language, difficulties in using the language in writing and orally, thus creating problems with communication.

7.2 Results from the pupils' questionnaires (pre-post)

General information

The questionnaires were handed to the pupils by the teachers because the questions needed to be translated in sign language in order to facilitate children filling them in. One of the pupils declined to participate in the data collection, thus the pupil did not complete any questionnaire. The reasons behind why the pupil did not answer the questionnaire are unknown, however one of the reasons might be that the pupil had linguistic difficulties both with written Greek and GSL, thus the pupil was unable to complete it. From the five pupils that agreed to complete the questionnaire, four of them were valid as one pupil completed only the post-study questionnaire and not the pre-study one. This was because the pupil did not attend school the day that the questionnaires were completed. Therefore, the analysis will be focused on four questionnaires, which is a representative sample of our population.

Ideas about heat (results)

As observed in the previous schools, the pupils of this school also connect the concept of heat with a hot object or a heating source (look at alternative idea 2.1.1). More specifically in question 3, the pupils consider that the reason the water bottles are getting warmer, is due to a stove or a radiator (hot objects), and sun (heating source). An interesting point that the pupils in this school express is that they mention "friction" or "hands" in order to indicate the exchange of energy between our body and the water bottles. In question 9, the pupils give a definition of heat as "something fluid, like air or breath (alternative concept 2.1.1). For example, one pupil mentions "heat is when we exhale" and another one claims, "heat is our warm breath, something that makes warm our cold hands". The third pupil is connecting heat with "hotness" (high temperature), whereas the other provides no definition at all.

In the post-questionnaire, the same pupil in question 3, replaces the idea of stove (hot object) with the idea of gas (heat in a gaseous form). The concepts of friction of hands, sun and radiator remain constant, so we can say that in question 3 there is no significant difference from the pre-questionnaires. In question 9 in the post testing, one of the pupils defines heat as something hot (alternative idea), the other remains constant in his opinion about heat being connected to the hot breath (alternative idea: heat in a gaseous form). However, there are two pupils that have changed their definitions; one of them refers to heat as two entities by writing the words "warm, cold". Although this idea still belongs to the alternative ideas, it is however better than connecting heat with one entity. In this specific case, the child explains in different ways of understanding with his/her senses the existence of heat. By connecting the concept of heat with two entities instead of one, the child has gone a little further and

closer to the scientific way of thinking especially if we consider the linguistic difficulties of this class. Finally, the last pupil explains heat by referring back to the story and give a definition as “heat is girls that move”. This is very important because we can see in practice how the story helped the pupil to develop his/her thinking and provide him/her the tool of explaining a very complex scientific idea. What it needs to be noticed is that in the pre-questionnaire, the pupil that did not express any definition of heat, now he/she actually tries to give a definition through stimuli that had from the whole project.

Ideas about thermal conduct (results)

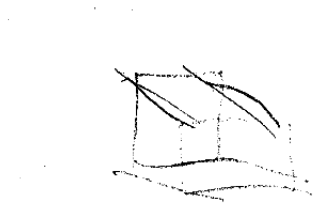
In contrast with the other two schools, in the first and seventh question, the pupils do not choose the woolen fabric as a conductor, and they seem to disregard it both in the pre and the post questionnaire. Therefore, the pupils did not present any change in that alternative idea (2.2.1). In the question 5, three out of four pupils chose the correct answer, which is the metallic plate. However, the reasoning that they gave was that the metallic plate is suitable because it is a source of “coldness”, which is connected to the alternative idea about metal as a source of “coldness”. The same reasoning is observed in the post-questionnaires as well. However, in the post-questionnaires there was a pupil that provided the reasoning as “the girls must leave”. In this pupil opinion, we can see that the child perceives metal as a conductor that can make the “heating girls” from the story to “leave the toast”. Regarding question 6, the pupils have chosen both in the pre and the post-questionnaires the metallic can in order to preserve the milk cold and the reason behind their choice was the metal would impede the milk from getting warm. However, in the post-study questionnaires there is one pupil that chose Thermos flask to preserve the milk cold instead of the metal, because as he writes “I do not want girls to make my milk warm”. This is a small success if we consider that the same child had chosen the metallic can in the pre-questionnaire and we can see how he changed that alternative idea through the project process and the story.

It is positive that in question 4, which discusses the conceptualization of two entities, three out of four pupils choose the wrong answer in the pre-questionnaires, whereas in the post-tests, the same number of pupils choose the right answer that does not distinguish heat into two entities. In question 8 that concerns also the two entities of heat, there is no change in the pre and post answers. Regarding the color choice in the question 6.3, the pupils express in both cases that the suitable color is grey/metallic due to the fact that they consider the metallic material as insulator.

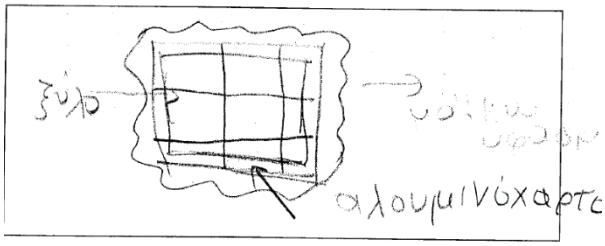
In the second question where the pupils were asked to design a picture of how they think the materials of the first question are placed, there is a big difference in the pupils’ design before and after in terms of the details that they use in their designs. We should take that into consideration because they were expressing their ideas by drawing and that overcomes the linguistic barriers. Some examples are:

A:

Before

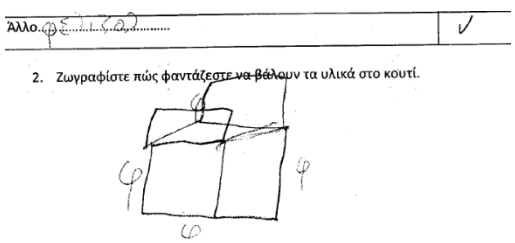


After

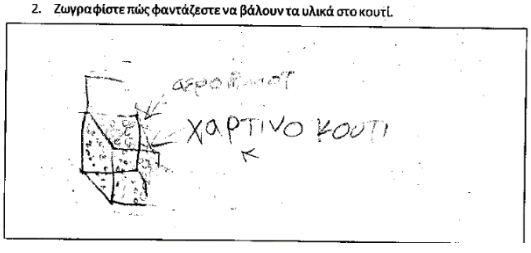


C:

Before

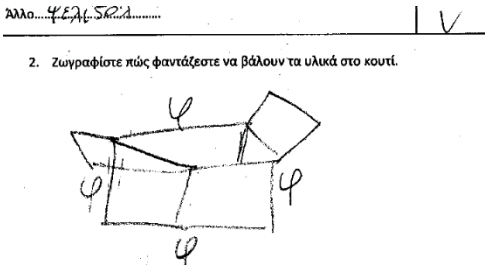


After

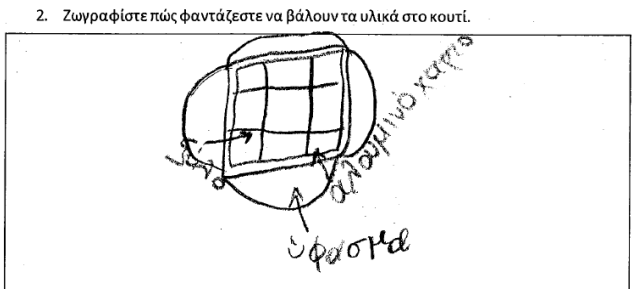


M:

Before



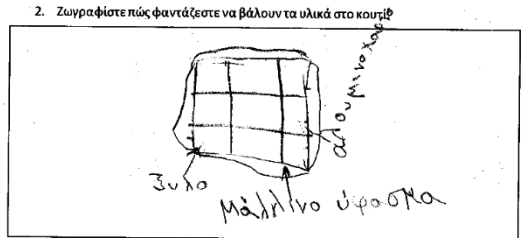
After



Z:

Before

After



As is observed, the pupils' drawings are more elaborative and include more details after the project. This might be an indication of a better understanding of the problem discussed (how to carry the cold bottles). What is impressive in their designs is that they all use insulators even though they do not choose them in the previous question. More specifically, three out of four drawings have on them the words "woolen fabric" that it did not exist before. Although almost none of the pupils chose in question 1 the woolen fabric, they seem to use it when it comes to make a design of the box. A reason for the pupils not choosing the woolen fabric in question 1 might be attributed in linguistic difficulties not in the persistence of their alternative idea. The drawing here indicates that we might have an alteration in the idea that the woolen fabric is a conductor since all the pupils include it in their design.

Summary

In conclusion, with regards to the questionnaires' results from this particular school, we do not observe any significant changes. Only one pupil seemed to follow the model that the story presented in order to explain heat in a more scientific way. Furthermore, from the designs of the pupils we can see that they use the woolen fabric to keep the cold bottles cold, even though they have not chosen it in the previous question. This might be an indication of change of the alternative idea concerning the woolen material. The other ideas of the three pupils seemed to remain solid in the post-testing. There were small changes in some questions of the pupils' post-questionnaires that although they do not reach the scientific way of thinking, they are equally important if we consider the pupils' extreme difficulties. Explanations behind the results of the questionnaires will be given later in the analysis of the opinions from the teachers.

7.3 Results from the worksheets

The pupils of this school focused mostly on three parts of the project: 1. The story, 2. The experiments and 3. The final construction. Although some of the activities proposed in the plans were not conducted, the pupils managed to complete the final task and make valuable observations to the experiments. They mostly worked with the worksheets that I proposed, where they documented the materials they used for the final construction and why they thought those materials are good to preserve the ice-creams cold.

Although their justifications are very simply written, they give us interesting information on how the pupils thought about their construction. When I arrived to the school, all of the pupils made a presentation of their constructions to me and they provided explanation of how they made it and why they chose insulators instead of conductors. Some of the pupils used the model from the story with the little girls as it was difficult for them to remember the terms "insulator" and "conductor".

In the documentation that I got from the teachers with the writings of the pupils, there was also some texts on how they interpreted the results from the experiments. Specifically, one of the pupils in the experiments with the balloon that inflates when we warm the water in the bottle that is connected to it, the pupils mentions: *"Heat was transferred from the warm bottle to the balloon and it pushed the balloon to blow"*. This specific pupil is gradually starting to understand of how energy transfers from the bottle to the balloon. The above explanation is very close to the scientific thinking is we take into consideration the linguistic difficulties of the pupil. Pictures from the experiments and the final construction can be found on Appendix 10.

7.4 Results from the interviews from the teachers

The teacher's perspective

Due to the fact that the project was conducted in two classes (fifth and sixth), there were two teachers that cooperated to conduct the project. Therefore, I will present the perspectives and opinions of both teachers as I conducted interviews with both of them. One of the teachers was deaf so I booked an interpreter that helped with the communication between GSL and oral Greek. The other teacher is hard of hearing with good skills in lip-reading, thus we did not need an interpreter and we conducted the interview in oral Greek.

Both of the teachers seem to express similar ideas when asked about their impression on the project even though they were interviewed separately. The female teacher mentioned that the whole project was worthwhile implementing in her classroom, because the kids had a great opportunity to learn more things about the physical concepts of heat and conductivity since the lesson of Physics is not taught in the school. The male teacher claimed that it was a nice project in general because the pupils worked as a team and it was a great opportunity for them to cooperate. Characteristically, he mentions:

"Previously, when we had other projects, they were competitive with each other, but now in this project we observed that they helped each other, there was cooperation and solidarity".

The female teacher also commented on the structure of the plans and whole design. She expresses positive ideas about the design and she specifically says:

"Regarding the projects and the teaching plans, I think they are the most important tools and I consider them necessary. I felt that these would make it easier for me to direct and make the children better understand the natural sciences, because children do not know about Physics. When I took the teaching plans and started to apply them inside the class, I saw that the children took the initiative to participate on their own, which for me was the most impressive thing."

In her opinion the design not only help her as an educator and provided a guidance in her teaching, but also, she saw positive results to the pupils' motivation and learning inside the class.

However, both of the teachers express some worries about the theoretical part of the project with the story that, in their opinion, did not work as well as expected. More specifically, the male teacher says that the thing that he wanted from the project was to have more pictures, to be more illustrated. He says: *"The plain text that you provided was a mistake. But if you described it with pictures, it would be better. It is easier for the deaf kid to see the picture and connect parts of the story slowly. I think that the practical part was a success, I am not sure, thought, about the success of the theoretical part".* If we take into consideration the extra difficulties of the pupils, besides the hearing loss, then an illustrated text might have been more effective. However, the story was not illustrated by its authors and illustrating the story was not possible for practical reasons.

These opinions are connected and derived from their general ideas about Deaf education. More specifically, both of the teachers highlight the importance of the visual stimuli as the fantasy skills alone are not enough for a deaf person to accumulate the knowledge according to their opinions. Specifically, the male teacher argues that the Deaf want optical stimulus in order to learn and that sign language is a picture, resulting in something tangible, rather than abstract concepts hovering. Connecting to that idea the female teacher supports that the Deaf people are more visual people because they read the expressions and they are very curious because they use their eyes to observe everything and they have a more intense desire to explore the unknown. Just because they are visual people, when they learn something new, they want to see it, she adds. As we can observe the two teachers believe in the visual stimulus when teaching a D/HH child. For this reason and despite the fact that the text was not illustrated, the researcher provided a lot of pictures that connected with some of the words inside the text (e.g. picture of a lizard, a cave, the glasses), pictures with examples of how previous schools worked with their constructions (Kemou,2014), videos of the experiments and a board for the teachers to pin all the images in order to be visible to the children while they were reading the story. In addition, it was strongly suggested that the pupils should not read or listen to the text, but the teachers interpret the text for them in sign language.

Furthermore, in different parts of the interview the male teacher specifically says that the story was not well-structure to fit the needs of the D/HH pupils. Instead, he proposes to structure the text piece by piece. For example, he thinks it is better to have seven stories rather than one and, in every story, to have a solid example of a concept. For instance, in the first story they can work with the words "hot" and "cold". In the second or third story they can have examples of hot and cold, so that the deaf can perceive one concept and then move to the next one. However, in my perception, that way he proposes it would make the pupils more tired because there is not a continuity between the stories and thus not emotional connection to it. By giving solid scientific examples of the concepts, there is not any differentiation from the traditional ways of the schools' books of science that the research has already proven to be inadequate. He continues his thinking in reforming the story by saying:

"I want to have multiple choice questions under the questions [in the story] and 4-5 choices and one of them to be right and give to the child the opportunity to choose the right answer and see if they understand what they are reading. So first the pictures, then the text and then questions and exercises"

This idea, in my opinion, finds me in disagreement as the children should be free in creating their own meaning when reading a story and not have ready-made answers to them. There are no right or wrong answers in a text in my view. I was more interested in letting the children formulate their own opinions instead for choosing an opinion from a list.

As mentioned in the analysis of the previous interviews, the ideas that the teacher has about Deaf education and teaching influence the way he/she sees the learning outcomes or evaluates a project. For this reason, it is interesting to present the ideas of the teachers in this school about teaching of the Deaf because these ideas have influenced the teaching process, the perceived learning outcomes of the pupils as well as the ideas about the positives and the negative sides of the project.

Apart from the claim that the male teacher made about wanting more visual stimuli, he argued that the deaf need step by step learning in order to climb in knowledge, in order to learn to separate things and have higher motivation in learning something more than they already know. For this reason, in the planning that was provided to the teachers, it was suggested that they divide the story and the planning of the construction in three parts. Every teacher had the opportunity to separate the text in more parts if they deemed that the pupils would learn better.

The female teacher claims that the best way for a D/HH to learn is though storytelling. Connecting with her ideas that D/HH people function better with visual representations, she argues that Deaf people focus more at what they could see rather than a written text. Generally, they are not very good receivers when listening to and reading a story. They like to tell and sign stories to each other and learn through them. She adds:

"Education and learning through storytelling is important for them or by sharing their own experiences or get involved in a theatrical game with small dramatizations".

She also highlights the importance of the experiencing learning by arguing that D/HH people fingerspell the difficult scientific terminology without actually understanding what the words means. They need to experiment and make constructions and apply the knowledge in order to understand and remember the words. Sometimes they try to memorize what they see even though they do not actually understand a word in depth. By using experiential learning, they can memorize the words better and understand the concept or idea behind the word.

To sum up, both teachers were satisfied with the whole process of the teaching intervention. Due to their ideas about D/HH people learning better with visual stimuli, they both deemed that the story should have more pictures or it should have been illustrated. They think that it is important for the Deaf, apart from the pictures, to have step by step learning and the introduction of practical work that is combined with the theory.

The teaching process

I had contacted the teachers several months ago before we meet in person in the middle of January and I explained the teaching process providing them both with the plans. I informed them that it was important to read the plan and when I arrive at the school we can discuss the details that they find confusing. However, when I arrived at the school I noticed that the teachers had barely read the plans and they expected me to explain to them what they will do, which was difficult if we consider that we did not had an interpreter with us. I insisted on reading the plans and then send me follow up questions. They requested that I simplify the text and take out some of the activities. For this reason, I took out some of the experiments and I replaced them with videos and I reduced and simplified the questions for the text. We agreed that they will have two months to implement the project and after two months I will come back to make the interviews. The time passed and approximately two weeks before my arrival at the school I sent a message to the teachers to remind them that I had booked an interpreter and I will fly to Greece and come to the school in order to do the final evaluation of the project and take the questionnaires from the pupils. To my surprise tone of the teachers informed me that they started with the project in January, but they left it on the side all this time because they were pre-occupied with other projects. Unfortunately, I could not cancel my plane tickets and unbook the interpreter so I could not provide more time to them to continue with the project. We agreed that they would prioritize it with the time that was left and hopefully it would be done in the two weeks. In the interview with the female teacher she described how they distributed the time in order to complete the project by the time I arrived. More specifically she says:

"For some weeks, we did not engage with the story inside the classroom. However, after we have talked and decided to prioritize it, we did not teach the rest of the subjects at all. For one week, we taught the story to the children continuously"

Therefore, in order to fit all the planning in two weeks the teachers decided not to teacher the other subjects of the regular program and instead focus only in the project.

This delay in the timeframe from the part of the school created huge repercussions for the correct implementation of the project, and the time that was given to the pupils to focus on the story and on the construction. According to the photos that they provided from the lessons and what they described to me, they disregarded some of the activities proposed and focused more on the story, the experiments and the final construction. They divided these three parts of the plans such that the female teacher was responsible for the teaching of the story and the interpretation in sign language, and the experiments and the final construction was handed to the male teacher. As far as the process of the story is concerned, the teacher focused more on the linguistic understanding of the text rather than critically discussing the context of it through the questions that were proposed. The teacher described how they decide to work with the story:

"I decided to condense the story from 10 pages into 5 to 6, having said only the most important things. I read every paragraph together with the kids. Afterwards, we interpreted it in sign language and then combined it together with the spoken one. Then I repeated it to see if they have understood the first paragraph because if I have read the story from the beginning to the end, the kids would feel lost. We did every part twice, because we worked on every paragraph. I tried to give the opportunity to the kids

to make assumptions about the story's plot first in order to tell their opinion regarding what they think it is going to happen. For example, they said "I believe that Dimitris is going to make it"

As we can see from the description, the teacher interpreted the story in sign language after condensing it and worked with the language of the text in every paragraph. Unfortunately, there was no time to dedicate to deeper analysis of the text, so they were limited in making assumptions. In another part of the interview the same teacher claims that although they used sign language, they mostly focused on the oral teaching of the language. She specifically mentions:

"Me and the other teacher based our teaching practices very much on the oral teaching. We were teaching orally in the beginning, the children wrote, but we helped them as they could not write on their own"

Different studies (Suzuki & Notoya, 1984; Livingston, 1997; Cicourel & Boese, 1972; Gregory, 1998; Strong, 1988) indicate that the oral teaching in D/HH children is not as effective as bilingual based instruction and it is not necessarily connected to the development of understanding the written language.

The male teacher that was responsible for the teaching of the experiments and the final construction, used also sign language as he is Deaf himself. He describes his part on the project as such:

"I worked the project mostly with the Internet, with material I made myself, and the interpretation in sign language was done together with the other teacher. We cut parts out of the planning and we made it smaller and signed everything. I involved in the part with the internet and the construction that we had to make. We used a lot the projector and YouTube because it was more interesting to them".

Therefore, from the rest of the activities that were not connected to the story the teachers did the part with the experiments and the final construction. Most of the experiments were observed in a digital way rather than doing them with their own hands. During the experiments and in the constructions the teachers did not worked with the mental model that the story provided, thus activities such as the representation of the girls with colors and plasticine were not realized.

To sum up, from the five teaching phases that the theory suggested, the teachers:

1. Applied the first phase (Orientation of the pupils) by discussing the problem with the ice-creams with the pupils
2. Did not apply the second phase (Projection of pupils' alternative ideas) since there is no mention in the interviews or in the photos/documentation they provided me about documenting how pupils think about the problem.
3. Applied the "Introduction of the new knowledge" phase by processing the story and conducting the experiments. They did not discuss the role of color in absorbing heat.
4. Did not apply the "application of the new ideas" phase. Although they fixed the insulation box at the end of the intervention, they omitted the part where they apply the model with the "little girls" in the whole process. For example, they did not explain the experiments with the model, they did not justify the choice of the materials by using the model and they did not do representations of it with colors and plasticine.
5. Did not apply the metacognitive phase due to lack of time at the end of the project.

The reasons why these phases were not applied may be the lack of time, since the teachers did not follow the original timeframe or they did not understand how to teach the model and implement in the process.

During our discussion, the female teacher mentioned their role inside the class during the project. She specifically says:

"We let the kids free to imagine. Me and the other teacher did not intervene in their thinking process. We intervened only when we had to interpret the story in sign language"

This idea that the teacher expresses is in disagreement with the characteristics of the role of the educator that the theory suggests. According to the theory the educator is responsible to help pupils realize the alternative ideas and aid them in navigating in their cognitive process. However, the description of their role comes in accordance with the theory when it comes to provoking curiosity and encouragement to investigate through the experiments and the internet exploration that they did.

At this point finally, it is important to mention the previous teaching practices in the school concerning the subject of natural sciences. Both of the teachers inform us that the school does not teach the subject of natural sciences to the children but instead they focus on Greek and Mathematics. The male teacher mentions:

"It was the first time that those kids had physics because we only have time to teach language, math and sometimes history. We had physics in the old days, when I was a child. It included mostly questions with no practical part, with a paper with some exercises like put the word in the right sentence and multiple choice".

The fact that the subject of natural sciences had not been taught in the schools before raises many questions and thoughts about the perceived importance of the subject and the expectations that the schooling system has from the D/HH pupils. The non-existence of previous experience in teaching science and especially with the conceptual change teaching method influences the whole teaching process both from the part of the teachers and the part of the pupils as receivers because they have not trained in the scientific way of thinking.

Motivational issues

When it comes to the questions how the storytelling influenced pupils' motivation, the two teachers disagree. The female teacher, who was responsible for teaching the story in sign language, attests that the story created positive feeling in the pupils. On the other hand, the male teacher claims that the story created negative and deactivating feelings in the pupils.

More specifically the female teacher mentions that the children were very curious about the story in the beginning and they were very excited about it afterwards. They had the lust to learn something new and she realized that from the first moment. In the second part of the story, the children's attitude changed and they seemed to be more willing to learn than in the first part. In general, she thinks that they liked the story and they were expecting to hear about it. She provides an example by saying:

"For example, during the lesson, when I showed that Dimitris seemed confused and was trying hard to find the solution, the children started to guess the end of the story, even before we get to the end. Eventually when they did, they were happy for their correct guess. The kids were screaming happily, they were very excited and they had that feeling of joy as when someone sees something new for the first time"

From the description of the teacher we can see positive and activating feelings like excitement, lust, willingness, like, expectation, happiness, joy. According to Pekrum *et al*. (2002, as cited in Sinatra & Mason, 2008) the above emotions can have a positive effect in learning and conceptual change as they increase motivation and critical thinking (see ch. 1.6)

On the other hand, the male teacher reports that when they read and signed the dialogues of the text the pupils' felt indifference and boredom. Those feelings are characterized as negative and deactivating as the theory informs us and they can contribute to the diminishment of motivation, declined attention to the task and superficial cognitive process.

The different opinions of the teachers regarding the motivation they saw in the pupils might be influenced by the ideology they have and the way they see the storytelling process in general. In the previous chapter we noticed that the male teacher did not like the story as it was not as illustrated as he expected. Specifically, he mentions that the story was a "burden" to the whole process. On the other hand, the female teacher has a more positive view about the story and she deems that it actually contributed in pupils' learning.

Regarding the rest of the activities in the plan, such as the experiments and the final constructions the teachers are in agreement about the pupils' motivation. The female teacher mentions that although the pupils felt some stress in the beginning on how to make the construction, at the end they found it very interesting and they were very curious. The male teacher verifies what the female teacher says by mentioning that they found the videos, experiments and construction very interesting. He provides an example of the pupils' behavior inside the class:

“In the experiments yes, they were all standing, “why do you do it in this way” they kept asking. Some of them understood how to initiate the experiments, I showed them the cause and then the children were keen to continue. For example, I had forgotten the water in the fridge, and we had to take it out at noon and the kids remembered it and they said, "The experiment, the experiment! We have to get the water out.” They were open and motivated with that process.”

From the description we can see that the pupils developed a situational interested for the practical part of the project as it was more visual and it included hands-on exercises. According to Sinatra & Mason (2008), pupils’ situational interested can influence the cognitive performance and have a long-term impact on personal interest and the idea of importance of natural sciences.

Positives and negatives of the project

Positives

Regarding the positives of the whole process the two teachers commented the three parts that they worked the most: the story, the experiments and the final construction.

Concerning the story, the female teacher claimed that it was better that the pupils saw the conduct of heat through a story and using the metaphor of red girls moving instead for using the terms “conductors”, “insulators” and “energy” because that would have confused the pupils. She also adds that she thinks that the pupils would enjoy participating in a project that had storytelling. The male teacher, on the other hand, had some objections about the structure of the story that we also mentioned above. However, he specifically says that he liked the plot and the questions, but he did not deem that the structure of the text was helpful.

Furthermore, the two teachers shared many positives when it comes to the practical part with the experiments and the construction. The female teacher considers that the experiments were successful and useful in understanding the concept of heat. She says that the pupils were very excited when they put their hands in the different bowls with the cold and hot water and then felt the difference when they put it on the room-temperature water. The male teacher adds to that thinking by describing how the practical part helped the children learn:

“All the kids, I believe, they benefited, especially on my own piece of the construction and the projector, and on YouTube. They were asking themselves to see the balloon how it would rise from the heat and with the sun. They had other ideas as well, so we spend more time viewing videos and doing after their construction. They learned from this process. I believe that there was a change on how they were thinking at the beginning and how at the end of it.”

Negatives

When it comes to the worries and the challenges that the teacher’s felt, the two teachers focus on the story and self-insecurities that they had in the beginning. Specifically, the female teacher mentions that in the beginning she was not sure if children would be capable of finishing the project, because she was informed that they had no idea about natural sciences. She did not know about their level, because she was a new teacher at the school. In addition, when she became aware of the pupils’ low level, she was afraid because she was responsible for teaching the whole story to the kids. She worked as a substitute teacher at the school and as she mentions, she was feeling worried about herself, because she came at this school in the middle of the year and there were new children whose performance she had not evaluated yet.

Regarding the story, the female teacher says that the pupils faced some challenges with the vocabulary of the text even though she reduced the text to half pages and signed it at the same time. She provides an example below:

“I realized that they did not know the words. I was telling and showing them: “What is the name of it?” and they did not remember it. They knew, but they did not know how to say it, nor how to answer the answers below. For example, they knew the meaning of the word “sack”, but they could not say it, to express themselves.”

The teacher also mentions that the pupils had difficulties remembering the sequence of the events. During the theatrical game, the teacher points the order of the events in the story and they were trying to formulate small sentences in order to understand better, but still there was problem in placing the events in order.

The male teacher as mentioned in other parts as well, expressed his worries about the story's structure that he would like it to be presented in another structure.

Environmental context

In this part it is important to present how the classrooms atmosphere during the teaching of the project might have influenced the results. The male teacher mentioned that in the class there is a discriminative atmosphere that inhibits the smooth collaboration of the teams. He specifically says:

"There were different discriminations in the class. For example, the other pupils didn't want TH to participate because he is slow and you need to explain something to him many times. They were frequently signed to him insults and they made fun of him, they said "you are slow, we don't want you", there is this kind of discrimination. Same thing with A that is slow when he is writing because of difficulty that he has in his hands. There is this discriminating attitude from the kids unfortunately. For example, no one wanted to join the same team with A so I had to work with him and at the end he created the best insulating box and the best pupil of the class got very mad."

This situation of discrimination and competition between the pupils may have created a negative atmosphere in the classroom that is not productive and effective in order to have conceptual change. The teacher also mentioned to the negative attitude of the pupils towards any written text because of the difficulties that they face in reading and writing.

"Most of the kids couldn't write a whole sentence. One of the pupils, that is hard of hearing has some writing skills. The other children are very low. Once they hear the word "writing", they stop from their nature. Also, with their reading skills. The kids cannot read, we know that, it is a fact. The one pupil C knows how to read, but he understands only 50% of what he is reading, although they are in sixth grade".

Pupils' learning outcomes

When we discussed with the teachers their opinion about the learning outcomes of pupils from the project, the male teacher talked about the model that represented the movement of heat. He claims that that the model was not deeply understood from the pupils and it confused them. He mentions:

"There [in the mental model with the girls and the boys], it was everything blurry, maybe the signing was wrong when we interpret it, maybe they did not understand the words, the transfer, that the red girls are the heat and the blue boys are the cold, the message with the little girls was somewhat cloudy to them in the text. We had to explain them, to change the perception, and they again stuck in the little girls, i.e. they did not get into the concept of warm and cold. Everything was blurred there."

In his opinion, the pupils got confused with the metaphor with the glasses that the hero in the story sees the heat as little girls. He provides different reason of why the pupils could not see the mental picture. Besides the wrong interpretation and the lack of vocabulary from the pupils that the teacher mentions, I deem that other reasons might be the wrong process of the deepening and exploratory questions that were given for that part and/or the omission of a visual representation on paper or with Play-Doh as the plans suggested. The combination of the pupils' difficulties, the lack of the time due to changes in timeframe and the omission of the basic visual representations of the model in daily situations may have resulted in the difficulty in understanding the mental model of the story. The model was also not worked into either the experiments or in the construction and the justification of the materials.

The female teacher comment on the pupils' choice to use woolen fabric in their construction and how the story helped them understand that the wool is an insulator. She claims:

"The kids remembered that the hero chose the woolen fabric, because they remembered especially that part of the story with the shoes that tied his feet with the fabric, so that explains their choice. When

they hear something, they say: “Here we have woolen fabric” and is something that children do not hear very often. When they do not try something so often, they decide to test it and see if this is true or not, because children have not thought or heard about the use of the woolen fabric before. They had no idea of what woolen fabric is”

Regarding the experimentation and the videos that they watched, the two teachers agree that the pupils realized better the difference between “hot” and “cold” and they were critically thinking about what they saw. The female teacher claims that the pupils utilized the knowledge and the conclusions the made from the experiment to enrich and justify the construction. The male teacher completes that thought by providing an example of one of the pupils that impressed him.

“There was this child, when we made the construction that he himself began to think about how to cut it off, which I thought that he would definitely need the help of the teacher but eventually he worked alone and began to discuss the construction like "if I put glue in this way, it will fall. If I put glue in that way though, it will not fall, it will get air, I had to put glue on the top.”. This particular pupil impressed me. And then I saw that they mimic each other and talked to each other after they found the solution themselves on how to make the construction”

Therefore, the pupils enriched their knowledge more in the experimenting and constructing process rather than in the storytelling according to the teachers.

7.5 Conclusions

In conclusion, from the results from the questionnaires of the pupils, we did not observe any significant change in the pupils’ ideas before and after the implementation of the project. The only difference is in the pictures of the pupils that include the woolen fabric even though they have not chosen it in the questions. From the interviews with the teachers, we observe that the plans were not followed as proposed, both in regards of timeframe and using the mental model in connection to the other activities (experiments and construction). Because of that limitations and taking into consideration the different difficulties of the pupils that are not connected to deafness, the teachers support that storytelling did not help the pupils alter their conceptual ideas about heat and thermal conductivity. However, the experimentation and the construction augmented pupils’ motivation. The storytelling part, on the other hand, finds the teachers in disagreement about the motivation the pupils presented. In commenting about the construction and the problem-solving task, the teachers report that the pupils succeeded in completing the task and it was helpful in relation to the motivation and learning.

7.6 Summary of findings

In the chapters 5,6,7 we have analyzed in detail the results from the schools and we interpreted them according to the chosen theory. Over the next chapter, a summary is provided of all the results from all the schools in connection to the research questions posed. It provides answers to the questions according to the analyzed results from the three schools for Deaf and hard of hearing pupils. The combination of the two research sub-questions can provide an answer to the central question about storytelling and natural sciences. The task of the final chapter (8) will be to discuss those results and draw final conclusions from them.

Chapter 8: Discussion and conclusion

8.1 Overall summary of results

Before connecting the results back to the literature, it is perhaps worthwhile first to summarize the results reported in Chapters 5, 6 and 7 for schools A, B and C. The questionnaires' results from the three schools suggest that all of the participating pupils have some alternative ideas about the concepts of heat and thermal conductivity. Some of the ideas about the concept of heat include the perception of heat as fluid substance (see ch. 2.1.1.1), the perception of heat as the thermal source (see ch. 2.1.1.4) and the usage of two entities to explain the thermal phenomena (see.2.1.2). For the pupils of the first and the second school, we can argue that there is a conceptual change on their perception about heat as some of the pupils use the mental model that existed in the story and some of them are using the definitions that are close to the scientific one. For the third school, we observed no change for the ideas of heat. Regarding the alternative ideas about thermal conductivity, we observe that the pupils possessed many of those ideas before the conduct of the project, some of which include insulator that generate heat like the woolen fabric (see. ch. 2.2.1), conductors such as metal absorb and maintain coldness (see. ch. 2.2.2) and that insulators, like the insulating box they created, are purpose driven (see ch. 2.2.3). In the post-questionnaires, the pupils from the first and second school seem to have a certain change in their alternative ideas about thermal conductivity and especially they have changed their opinions about the role of woolen fabric and the metallic material. They also seem to understand the role of the color in the absorption of heat. The pupils from the third school, although it is not very clear from their answers, use the woolen fabric as an insulator in their designs and in the final construction. However, there is no evidence indicating any change in their ideas about the metallic material.

From the discussions with the teachers, all of them seem to be positive about the results from the project in general. They all expressed satisfaction about the practical part of the project that included the experiments and the construction of the insulating box. In three of the four teachers expressed also positive opinions about the storytelling and they labelled it as "helpful". All four teachers in the schools reported augmentation in motivation (goals, interest, emotions, self-efficacy and control beliefs), while they suggested that the additional activities connected both to the story and to the construction were elevated pupils' interest. The teachers reported that all of the pupils completed their final task by finding a solution to the original problematization. In all of the schools the teachers mentioned the same learning that the pupils did as the questionnaires also indicate.

Taking these results into consideration, we can provide an answer to the main research question, which asks if a storytelling-based project can improve pupils understanding about the concepts of heat and thermal conductivity. The positive conceptual changes from two out of three schools, in combination with the teachers' testimonies about better understanding and elevated motivation, seem good support for the conclusion that the storytelling-based teaching intervention helped the pupils to acquire a more scientific understanding.

8.1.1 Research question 1

The main research question was divided in two sub-questions, the first of which is if we can observe any difference in pupils understanding before and after the storytelling-driven project. From the examination of the questionnaires, we concluded that the pupils from the two out of three schools presented conceptual change and they differentiated from the original questionnaires in their misconceptions about heat and thermal conductivity. The teachers verify that conceptual change by mentioning this similar conceptual change is also present in the results from the pupils. Changes are observed in the conceptualization of heat and in the thermal conductivity, especially regarding the roles of insulators and conductors. Although we can see a conceptual change (see definition in 1.3.2) before and after the implementation of the project, we cannot say that the pupils have reached the scientific way of thinking yet, as that required many years of training in natural sciences and the alternative

concepts are very well established in the human brain needing many years to fully alter. However, this project provided a good example of a holistic conceptual change.

The pupils of the third school, due to misapplication of the project and external school factors, present only a change in the concept about the role of insulators and specifically in the role of the woolen fabric.

8.1.2 Research question 2

The second research sub-question concerned the teachers' beliefs about how the story-based project helped the pupils in three sections: a. better understand the concepts of heat and thermal conductivity (conceptual change), b be more motivated in learning about the scientific concepts and c. provide a solution to the problem that was posed to them.

The results from the interviews from the two first schools come in accordance with the results from the pupils' questionnaires. The two teachers report that there was an alteration in the pupils' ideas especially about the thermal conductivity of the woolen fabric and in the conceptualization of the heat. The story and the metal model proved to be a useful tool in communicating and formulating the two concepts. In the third school the teachers also report alteration in pupils' ideas and learning that achieved mostly with the practical part of the project rather than the mental model of the story. The two teachers are in conflict regarding the benefits of the storytelling to pupils' understanding of the concepts, whereas they are in accordance about the benefit of the practical part.

Regarding the motivation, the three out of four teachers report elevated interest and positive activating emotions when reading the story, whereas all the teachers report high performance goals, confidence and interest about the experiments and the final construction.

Finally, all of the teachers highlight the importance of the problem that the pupils had to solve and the process of solving it in their learning. All of the pupils participated in construction the insulation box and provided creative solutions to the problem. The construction process was beneficial in accumulating the knowledge about the concept, but also it assisted pupils in developing their cooperation skills and critical thinking.

8.2 Discussion of the results with regards to Deaf studies

As we mentioned in the literature section (see ch. 3), the researcher has not found any influential literature on storytelling, science and deaf education in English thus using a triangle method with literature that connects science practices for the Deaf, importance of storytelling to the Deaf and storytelling with science for the hearing. In this chapter, it will be analyzed how the results rom this study has reinforced or challenged the current literature on the field concerning Deaf studies, narratives and science practices.

According to Sutton-Spence (2010), a very common way that D/HH pupils learn is through narratives, which they describe to each other using sign language. However, the narrative component seems to be missing from their education and especially in the STEM subjects, as many teachers find the connection between a humanistic and a positivistic subject difficult to handle in teaching (Μαργαριτη, 2012; Κουτσιούκης, 2011). From the results from three Greek schools that the project was tested, only one of them tough science as subject in the school, whereas the other two did not had natural sciences in the school program. The one school that teach science to the D/HH pupils are using a traditional way of teaching i.e. though textbooks and there is no clear connection to the humanistic sciences. However, after the implementation of the project, three out of four teachers report that the pupils learning was enhanced because of the usage of a story in the natural sciences subject. This is a verification that the pupils need more stories in order to understand better the scientific concepts.

Rutherford (1985) reports that narratives are valuable to the D/HH people as it has the ability to transmit cultural values. In the text that the pupils were given in this experiment, the pupils had the opportunity to discuss about the behavior of the hero's mother and friends when he unsuccessfully carried the water warm back to his village (appendix 6). In the results the majority of the teachers claimed that it was beneficial that the pupils could discuss and interpret behaviors from the story that

are connected to Greek cultural ideas. In that way, the story not only provided a mental representation for the teaching of science, but also it provided opportunities for the critical thinking of cultural values back in the time and compare to the cultural values that we have nowadays. Therefore, completing Rutherford (1985) we would argue that the narratives can not only transmit cultural values, but also give opportunities for interpretation and critical thinking of those cultural values.

Rutherford (1985) continues by arguing that narratives can help D/HH pupils in their understanding of the group's behaviors and norms. Indeed, during the analysis of the story in the class the pupils were called to explain the behavior of the hero, the hero's mother, the hero's friends and the role of the salamander. After interpreting their behavior, the teachers in two of the three schools provided examples of the behaviors found in the story but placing them in the school context. The teachers of these schools mentioned that this exercise was helpful in order the pupils to understand why sometimes their classmates, teachers or parents, behave in the way they behave in similar situations and at the same time to self-reflect with they own behavior under similar circumstances. In the pupils' worksheets from the school B (appendix 8), we can see the personal reflections of one of the pupils on the norms presented in the text and his answer on how he would react in similar position. Therefore, we would argue that the story helped the pupils understand better the norms from the life in the village, gave the opportunity to reflect on their own behavior and norms they follow and subsequently reflect on their own identity and morals.

When discussing the scientific practice in Deaf education, Wang (2011) argues that inquiry-based techniques helps the children make sense of their environment. A part of the planning of this school intervention involved some inquiry-based activities, mostly when the pupils had to investigate about the materials they used in their final construction. In the interviews with the teachers, one of them mentioned that some of the pupils asked their parents if they can give some insights in their problems, whereas other looked for information on the internet at their home. However, when we talk about inquiry-based techniques, we need to take into consideration that the three above schools neither provide individual computers/iPad to the pupils nor have school libraries, thus making the access to the information difficult. Moreover, none of the schools have science lab and many of them have difficulties in accessing material for conducting experiments. In this way, inquiry-based techniques alone are not enough for acquiring the scientific knowledge, specially when we talk about schools with not strong infrastructure. Therefore, we can argue that storytelling can be an aid in acquiring information about scientific ideas and models without needing economical investment.

8.3 Discussion of the results with regards to the CCT

In this chapter it will be evaluated the fitness of the theory in this intervention and how the results can enhance the existed theory on the field. First of all, one of the strengths of using the CCT is that it provided with an explanation and a conceptualization of how pupils' learning occurs i.e. through alteration of previous misconceptions. Based on that idea Driver and Oldham (1986) proposed a didactical model that would guide the teacher into using the CCT model. The didactical proposal was the base on which the planning for this intervention was developed. However, after taking into consideration the pupils' results and with combination of the feedback that was received from the teachers, I would claim that it is a complicated theory that most of the teachers are not familiar with. As mentioned in the drawbacks of the theory, most of teachers are not well-educated on using CCT which created obstacles in the communication between the researcher and the teachers. Furthermore, the complete alteration of the ideas can be achieved through the course of time and in certain cases it might never achieved if CCT is not used continuously. That can create disappointment to the educators and not so clear results to a research because the knowledge requirements become higher i.e. if we consider that the goal of the pupils is to reach the scientific explanation of a physical phenomenon. Taking into consideration the negatives of the theory, there are other theories such as problem-based learning or project-based learning that are close to the design that we had and it is more familiar to the teachers. The CCT is more oriented towards concepts, metacognition and realization of ideas, whereas a project-based learning is based more on Dewey's ideas about active learning and learning by doing. After having myself taught to hard of hearing children in Sweden, I would change the theoretical

background in choosing something that is more concrete than abstract i.e. a theory that is focused more in evaluating the results of the products of the pupils rather than ideas.

Besides some negatives that were observed, we can argue that some parts it was contributing to the whole process. For example, the theory provided a base for the interpretation and conceptualization of motivation of the pupils and it gave a concrete base in order to explain the emotions, reactions and goals the pupil's presented according to the teachers' point of view. If we take a deeper look into the three cases, we can observe from the results from the interviews with the teachers that pupils indicated an elevated motivation, positive activating emotions and high interest. This is deemed significant because motivation plays a big role in the formulation of mastery goals according to the theory, in the creation of stable base for total alteration of misconceptions and in the perception of importance of science in general. The lack of an organized curriculum and teaching practice in science in the Deaf schools, gives the impression that there are deep assumptions that there are no mastery goals in the D/HH pupils and misbeliefs that these pupils are willing to understand physics. In Greece, there is still beliefs that the D/HH pupils cannot study in university level, thus deep scientific knowledge is not important for their future careers. Expectations for D/HH people that are not included in hearing settings are very low, thus are labeled as "special education" even if there are no cognitive and learning problems in some of the pupils. In our results, we can see that two out of three schools the pupils do not have natural sciences at all in their program and the focus is more on language and mathematical acquisition. Therefore, the fact that these pupils came in contact with scientific concepts, achieved to learn the concepts discussed and actually enjoy the process, gives a strong message in the teaching stereotypes that are existing in special education in Greece regarding the subject of natural sciences.

Apart from the strengths and the drawbacks of the theory, it is good to go deeper in it by looking how the results can possibly extend or refine the theory on the field. According to sociocultural ideas "in learning theory, pupils come in contact with new ideas within a social context […]". Although ideas are embedded with the social interaction, we need to consider that for the deaf pupils, the social can be a little different than their hearing pears. For the D/HH, the social is divided in two "worlds", the "hearing world" and the "deaf world" (Harris, 1995). The two "worlds" share different languages, one language that is written and one that is more visual. The stimuli that the pupils have come from a bicultural/ bilingual environment, so we might argue that pupils can come in contact with new ideas on multiple social contexts and not a single context as they are leaving in a culture that differs from the mainstream.

In addition, as SCM for CCT suggest "sociocultural perspectives also focus on dialogue among members of the scientific community", meaning that when we talk about scientific knowledge, we talk about the scientific discourse among the members of the scientific community. Our results indicate that D/HH pupils do not choose to become scientists because science is neglected as subject in many deaf schools in Greece due to expectations about deafness. The scientific language is many times abstract and expressed in written or oral ways. D/HH people tend to function with visual stimuli or mental pictures like the picture in the story that it was provided in this research. In that way, we can say that scientific language sometimes is not accessible to D/HH as it is based on written academic language that many pupils (as in the above schools as well) do not use or have difficulties in using it. In some cases, there are not even signs that are specialized in terminology and are finger-spelled in GSL. Thus, it creates a picture that scientific discourse is something outside of the realm of the deaf community as it does not consider their linguistical needs. Therefore, if we want to make science accessible to D/HH we need to evolve the sign language scientific discourse so that D/HH people feel science closer to them. Also, in that way, schools would choose easier to include STEM subjects in the school program.

The main definition that Driver et al. (1994) provides about science learning is that "Scientific learning is considered to include passage from a social (shared) to a personal (internalized) level of scientific knowledge, and this passage is mediated through language." The results indicate that our pupils used sign language in every step of learning and it was very important to them in order to achieve science learning. If we take into consideration that sign language is a visual language we would argue that the definition is imperfect as it should include that the passage can be mediated through visual stimuli and images as well besides the oral and written form of language. Furthermore, when discussing what the alternative ideas are it is claimed that "Their application (pre-existing ideas) is related to the natural phenomena that they (pupils) perceive with their senses". However, we need to take into

consideration that pupils may have ideas that they do not perceive this their senses. As we observed, the pupils present ideas about how heat looks like and how it moves through different objects without actually see or feel heat when it moves within different bodies. It would be interesting to investigate what kind of ideas D/HH pupils have about sound and its properties that they cannot directly sense. In that framework, ideas can be also created through other stimuli that are not directly connected to our senses but are connected to fantasy and abstract thinking. So, in that case, after examining ideas in our science fields, maybe the description of the alternative ideas can be extent outside of perceptions created by our senses only.

8.4 Discussion of the results with regards to methodology

In regards to the methodology, we can argue that choosing a qualitative approach to investigate the problem, is the most efficient way as every school has different conditions, the pupils have different prerequisites and opportunities, and thus the results gathered differ very much between the three schools. The outcomes of every teaching intervention were subjected into influences of internal and external factors that are important to be taken into consideration in order to explain and attribute meaning to the results. For this reason, factors such as the environmental settings and the teachers' perspectives were investigated in order to if those factors influence the outcomes of the questionnaires of the pupils. The decision of including both questionnaires for the pupils and at the same time investigating the ideas of the teachers provided insights not only on the final pupils' results, but also on how the whole teaching process actually influenced the final results. Furthermore, the teachers presented the learning that occurred during the different phases of the teaching and how pupils reacted to the different activities. This is very important because sometimes the questionnaires on their own, may not present a clear image of pupils learning as we capture their ideas on a specific period of time without presenting the continuity of learning. This continuity and progress can become visible from the teachers' stories. In the analysis of the findings, the "thematic analysis" together with "meaning making" techniques were chosen which presented to be time and quality effective. Other techniques that could have been used were narrative techniques, but in that case, we needed to compare and contrast the stories from the interviews, which was not recommended due to the different nature of the schools.

When it concerns the preparation of the intervention such as planning, choosing story and discussing with the teachers, there are some things that it would be different if the research were to be done again. I deem that it would be more efficient for the planning if I would have travelled and familiarized myself with the pupils before writing the plans. In that way, I would have known what activities are better for each pupil group and if needed I would have made specific adjustment for pupils with special abilities. In the choosing of the story, the results indicate that the teachers would like that the text had more pictures. Although different pictures were provided, maybe they were not enough for pupils that base their understanding in visual stimulus. In that case maybe an illustrated version of the story would have worked better. Regarding the discussion with the teachers, it would be more effective if I tried to explain better the theoretical part of the study in order for the teachers to focus on the pupils' ideas. Furthermore, I deem that the presence of an interpreter during the explanation of the plans in the D/HH teachers, would have eased the communication.

Some issues that should be taken into consideration when conducting an intervention are the cooperation inside the groups, as the pupils themselves report in their interviews, which is not always guaranteed, and depends on every class and on how well the children have worked together on a collaborative level. In addition, the limited time of the program left no room for more insights into other heat-related concepts, such as changes in physical processes (melting, coagulation, boiling), but also to insist on the exploration of sophisticated alternative pupil ideas.

Some drawbacks in the methodology selected to investigate the research questions is that the researcher did not had direct experience of the pupils learning inside the class due to ethical reasons. Furthermore, interviews with the pupils would improve the idea about their learning and how the project worked inside the class, but that was difficult to be realized due to practical reasons. Regarding the results, it is deemed that the methods chosen was suitable as we had the opportunity to investigate both the teachers' and the pupils' views without put an extra linguistic burden for them with many and

complex questions. Interesting, however, it would be to see if these alterations of the pupils' ideas have remained one year later after the project occurred. It would be also interesting to see how the pupils have developed these ideas in physics in higher grades.

8.5 Future studies

If we take into consideration the limitation of the methods of this study, a new idea for future research would be to conduct a similar or the same study in schools and collect data with observations and pupil interviews in their language. Moreover, an action research design was chosen for conducting that study. However, due to time limitations, it was difficult to conduct a follow-up study and examine if the positive results that we observed from the pupils' questionnaires are durable within the course of time. Namely, a follow -up study would be beneficial in order to see if the pupils' idea about heat and thermal conductivity have last in time.

Our results indicated that in 2 out of 3 Deaf schools involved in this study in Greece, the pupils were not taught the subject of natural science at all. It would be interesting to investigate why teachers avoid this subject and what influences that decision. In order to have a deeper understanding of what influences the results of the pupils in these schools, it would be interesting to conduct a deeper examination on how the wider setting and the facilities of the school influence learning. For the same reasons, it would be productive to see the role of the teachers in pupils learning and more specifically their skills as sign language communicators and content specialists in the different school subjects.

Considering the limited literature that exist on the field, it would be productive if there was more research on storytelling and science teaching for the Deaf and hard of hearing using different stories and texts (e.g. comics, historical texts, science fiction) and discussing different concepts (e.g. sound, light, electricity etc.). More research would be also useful within the general area of didactics of science, as well as in the didactics of literature for the Deaf education.

Finally, interesting would be to see if we can have similar results in case we change some of the study's aspects. For example, would we have similar results if we decided to keep the same story but with another planning or theory or if we decided to have the same project but in another country? What would happen if we applied the same project in special education settings? Is it possible to adjust the planning for children with visual or memory problems?

8.6 Conclusions

There is a great need for a better formation of the curriculum for the Deaf and Hard of Hearing in the subject of science and more specifically introduce a framework that will lead to the transition from teacher-centered teaching into a pupil-centered one. The pupil should be a protagonist of his learning and an educational facilitator of knowledge who will respect and take into account the interests, the experiences and the initial ideas of children in order to build new knowledge. Through the interdisciplinary conjugation of techniques in the teaching of storytelling and physics, attractive learning environments can be created for pupils who, with the power of narrative speech, will aesthetically be fascinated, and at the same time be able to build new knowledge, arguing in practice about their initial ideas. This project was an innovative way of introducing science to the D/HH pupils, as well as it served as an example of teaching science for the teachers. The new learning environment has been an alternative way of approaching the concepts of heat, temperature and conductivity in a more human, comprehensible, entertaining and interesting way.

Obtaining scientific knowledge should be a part of pupils' education and have equal importance as other school subjects. The theoretical background was proved effective in not only making the teaching design, but also in interpreting the results that were gathered from pupil questionnaires and teacher interviews. The results, from a teaching project that was constructed for the concepts of "heat and thermal conductivity" combining storytelling, inform us that D/HH pupils can have many benefits in their learning and motivation when they are exposed to a narratives and experiential activities. In the

field of Physics, comparing the answers given by pupils from the initial and final questionnaire and the teachers' interviews, it can be concluded that most pupils, and especially those whose teachers were loyal to the planned intervention, significantly improved their understanding of heat and cold as scientific concepts after the innovative intervention of linking storytelling with Physics. It is therefore concluded that a teaching intervention that uses a storytelling approach to teach scientific concepts brought positive influences on deaf pupils' learning. For the researcher as well as for the teachers and pupils, the design and implementation of the innovative intervention has been a constructive and useful experience, showing new ways of organizing, managing and experiencing a classroom and learning, during a set of lessons in physics—and not only that subject—in elementary school.

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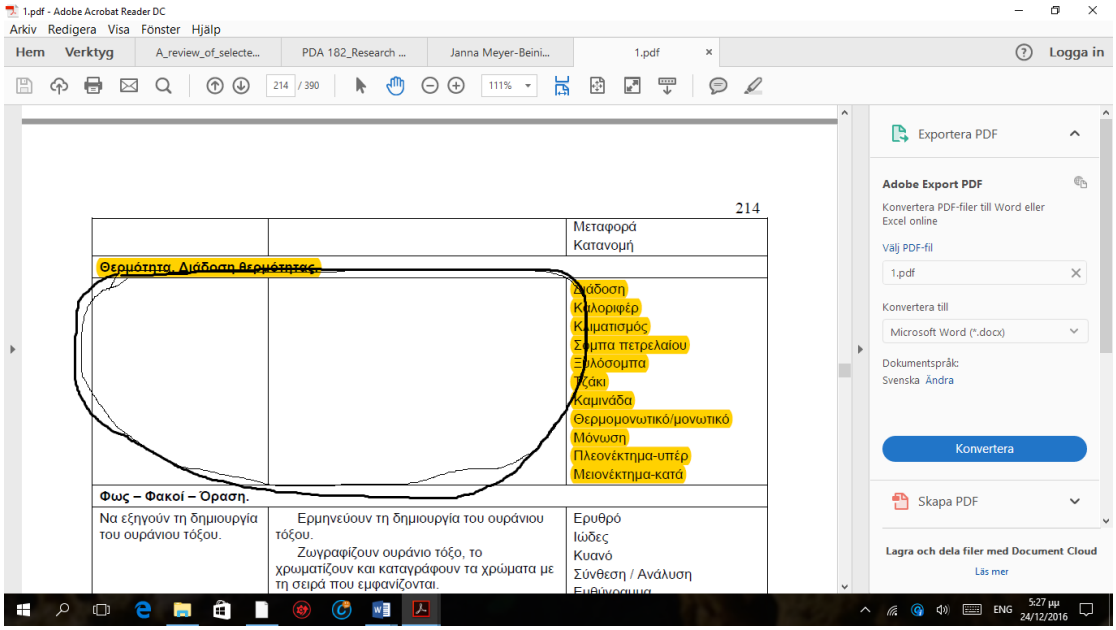
Appendix

Contents:

Appendix 1: The Gap in the Curriculum



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		Μεταφορά Κατανομή
Θερμότητα. Διάδοση θερμότητας.		
		Διάδοση Καλοριφέρ Κλιματισμός Σόμπα πετρελαίου Ξυλόσομπα Τζάκι Καμινάδα Θερμομονωτικό/μονωτικό Μόνωση Πλεονέκτημα-υπέρ Μειονέκτημα-κατά
Φως – Φακοί – Όραση.		
Να εξηγούν τη δημιουργία του ουράνιου τόξου.	Ερμηνεύουν τη δημιουργία του ουράνιου τόξου. Ζωγραφίζουν ουράνιο τόξο, το χρωματίζουν και καταγράφουν τα χρώματα με τη σειρά που εμφανίζονται.	Ερυθρό Ιώδες Κυανό Σύνθεση / Ανάλυση

The highlighted title is the chapter that is studied (Heat- Transfer of Heat) and the third column has only suggested vocabulary that the pupils should learn (From the top: Convection (of heat), radiator, air-conditioning, oil stove, wood stove, fireplace, chimney, thermal insulator/ insulating, Insulator, Advantage- for, Disadvantage- against). In the first column, there should be the general goals for the chapter and in the second column there should be the specific goals for the chapter. However, as we can see there is not goals in this section, which render the planning proposed in this research even more necessary.

Appendix 2: Specific Goals for D/HH pupils in the curriculum for Physics

The following text is an exact translate from the curriculum for the D/HH:

"In the lesson "Researching the natural world", in the primary school, it is sought the systematic introduction of the pupil to the meanings and the way of approaching and studying the natural sciences. For the development of the aim of teaching the lesson, it should be taken into consideration the mental development of pupils, the background knowledge that they have, their skills and desires(expectations), their social level and environment, the necessities that they exist in it, the time and the technological equipment that the teacher has on his disposal for the teaching of the lesson. Based on the above, the teaching of Natural Sciences should contribute:

To the acquisition of knowledge relevant to the theory, laws and principles that are related to the specific objects of Natural Sciences, in order the pupils to be capable of not only observing the natural and chemical phenomena, the procedures that are related to the organisms and their relation to the environment in which they live and record their observations, but also interpreting at the level that is allowed by the perceptive ability of their age.

To the development of the personality of the pupil, to the cultivation of independent thinking, love for work, capability of logical confrontation of situations and ability for communication and cooperation with other people.

To the cultivation of collective spirit of work for the attainment of mutual aims.

To the familiarity of pupil with the scientific methodology (observation, hypothesizing, concentration - usage of information from different sources and indeed with the use of technology and computer science, experimental testing, analysis and interpretation of data, drawing conclusions, generalization and construction of blueprints).

To the development of the pupils' skills and the cultivation of skills through the experimental and laboratory activities of the lesson, so as to be capable of evaluating the scientific and technological applications in order to, as a future citizen, be positioned critically across them and to hear about the positive or negative effects to the individual and social health and the environment.

To the discovery by the pupil of the contribution of Natural Science to the improvement of human's life quality.

To the pupils' knowledge about organization and of environmental processes and the acquisition of the ability to participate in the effort to solve social problems utilizing the knowledge and the skills that has acquired.

In their familiarity with the simple scientific terminology which will contribute to his overall language development"

Appendix 3: The questionnaires

The form of the questionnaires was the same before and after the teaching.

Pre- Questionnaire

School:_____

Class:_____

Date: __/__/ 2014

I am a : ☐ Boy ☐ Girl

Our school's headmaster had a very fine idea! In the summer, at the end of the school year, he wants to bring ice cream for the children and their parents, at the final ceremony! He does not know though, how to bring it without it melting....Not being able to think of a way and having a lot of work to do, he decided to forget about it. However the teachers of the 5th and 6th grade gathered and decided not to abandon this idea and told the headmaster, that the children would take care of this!

The headmaster did not believe the children would make it, but the teachers are sure about it! Finally the headmaster agreed, though under one condition : the teachers should not help their pupils so that the children would make it on their own!

However, your teacher decided to offer you some help, giving you the story of a young lad, Dimitris, who also wanted to carry something icy.

You must show that headmaster that you can make a perfect device that can help with carrying the ice-cream. Maybe the best even among the rest of the schools!

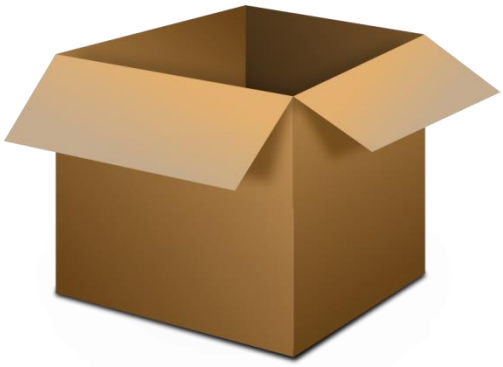
In order to achieve that, you should:

- Work with your team in order to work out what is it that makes the ice-cream melt, so that you can try and avoid it.
- Think about the story and find help in the hints hiding there.
- Work with your team and the rest of the teams in order to examine if your proposed device has problems and make it better.
- Consider any help you can get: from your books or other books, from the internet, your teacher, your classmates, the experiments.
- Think about your craft very thoroughly so you can present something handy.

Answer the following questions expressing your view freely, without any fear. It is no test and will not take a lot of your time! Answer sincerely, without asking around!

Concept/Idea Questionnaire

Mr. Dimitris, the headmaster of the neighboring school, has assigned to the pupils of 5th and 6th grade to make up a way of carrying ice cold water bottles, during the summer, for the football matches. They know its shape but there are many issues they have to decide upon and need your help.



1. What materials would you propose they use?

	Yes	No
Aluminum foil		
Wooden sticks		
Newspapers		
Woolen cloth		
Metallic Garden Wire		
Plastic Bag		
Other……		

2. Make a sketch of how you suggest the materials should be put together in the craft/device.

3. What does, in your opinion, make the water in the bottles warmer? Write as many reasons as you can think of.

They will get warmer because of...

1._____

2._____

3._____

4._____

4. George and Anastasia are having a discussion and are disagreeing on something.

George: This box can be used to transfer warm food and keep it warm!

Anastasia: But this is absurd! A thing that was built to keep things cold, it can't be used to keep things warm too!

With whose opinion do you agree more? Black the box that shows where you stand.

George Anastasia

5. Giannis, a pupil of the third grade, wants to eat his toast quickly. But, the toast just came out of the toaster and it's hot. His mother has left at the kitchen's bench one wooden and one iron plate. In what plate should he put his toast in order to eat it faster?

Put an X in the sentence that you think is correct.

- ☐ It doesn't matter which plate he puts it.
- ☐ He should put it on the iron plate.
- ☐ He should put it on the wooden plate.

Can you explain why?

_____
_____
_____
_____
_____
_____

6. Giannis would like to transfer his cold milk at school to drink it during the break, but he didn't know where to put it in order to carry it. Put an X in the material/s that you think will keep Gianni's milk cold.

Plastic Bottle	
Paper box	

Metallic can	
Glass bottle	
Thermos	
Other……..	

Why did you choose these materials?

_____
_____
_____
_____

What color, do you think, should have the object that you chose? Why?

_____
_____
_____
_____

7. Gianni's mother said to him that it would be better if he covers his milk with something in order not to touch it with his hands and gets warm. Put an X in the material/s that you think is better for Giannis to cover his milk.

Newspaper	
Plastic bag	
Woolen fabric	
Styrofoam	
Metallic garden Wire	
He can touch it with his hands; it won't get warm.	
Other……	

8. If Gianni's milk was warm, would you use the same materials?

Yes ☐ No ☐

If not, what materials would you advise him to use?

_____
_____

9. A pupil of the 3rd grade is blowing into his hands to warm them up during a cold day and is asking you what heat is. How would you answer him?

Heat is :

_____
_____
_____
_____

Appendix 4: The interview questions

Information and Consent:

The aim of the research is….

Do you accept to be recorded?

The data after the research will be…

Expectations before the implementations of the project

- What was your first impression about the project when you read the plans?
- Did you find it interesting? Did you think that the pupils would found it interesting?
- What was your opinion after reading the story? Did you think that it would help the pupils understand about heat?
- What challenged did you think that you would encounter?
- How science is being taught in this Deaf school? (didactic methods, didactic tools used before, challenges in teaching science, challenges in teaching about heat without the story)
- What was your expectations concerning children's motivation about the project?
- What was your opinion about the construction project from the pupils? Which are the advantages and challenges that you though children would have about the construction project?

During the implementation of the project

We will go the plans again analytically and, in every activity, I will ask:

- How much time did you need to finish the activity?
- How did you actually did it?
- Did you make any changes? If any, why and what changes?
- How did the children react at the beginning and at the end of the activity?
- How was their motivation when they were engaging with the activity?
- Did they said something that impressed you or you did not expect from them to say?
- What was the indications (facial indications, "a-ha" sounds) what made you understand that they are learning and they understand the contend of the activity?
- How did they argument their opinion?
- How was they motivation when reading the story/ engaging with the construction?
- Did they used the story in the experiments, the presentations and the construction project?
- What was challenging for them to understand in the story/ activities/ construction project?
- Did the pupils enjoyed the experiments? Did you think they were useful? How did they used the knowledge from the experiments to the construction project?
- Did you observe anything special in children's sayings or handscripts?

After the implementation

- At the end, what did the children found more interesting? The story or the construction?
- Do you think that if you had only the story (and not the problem or construction project), would the pupils have had still benefits in their learning?
- Do you think that you would you like to teach other scientific concepts again using storytelling? Would the children like that?
- In what way did the story help children's understanding? In what ways was that understanding visible? What indications or evidence would you offer in support of your judgment? In your view, does deaf children's understanding 'work differently', and was that difference visible in storytelling?
- In your view, did some children benefit more from storytelling than others did? If so, can you pinpoint differences in their learning?
- Was storytelling time-effective from a didactic/teaching point of view? (For example, what other methods might you have considered, and why?)

- In your view, is learning via storytelling more or less enjoyable to do? (You might for example discuss particular moments that went well or less well, or fun or discussions that you had together)
- What can you tell me about the language aspect of storytelling? (You might for example discuss the language modes that you/the children used in presenting the story and discussing it, how discussions took place, and whether some children were more, or less, included because of their language skills?)
- Did the children gave you the impression that they worked at home too in order to come prepared for the project (done internet searching, asking information from their parents, reading more sources)?
- What is your holistic impression about the whole procedure? Did you think it is worth to teach using storytelling?
- What are the benefits and challenged that you encounter during the project implementation?

Appendix 5: The plans

Teaching plan: « The freshest of waters»

The text is suggested to be taught in 3 parts. The first part will be from: “Once upon a time… with a light push, he enters it.». The second part is: “He was met with a dazzling light … He took out the two halves of eyeglasses», whereas the third part is “They each had an indent in the middle … traditional ice-cream ».

The class will be divided into groups of 2-3 people.

1st Session:

Activity	Description	Didactic goals
Introduction to construction project 10 minutes	The teacher mentions that the headmaster asked the pupils of the sixth grade to make a structure to carry cold ice creams at the end of the school year (in summer). The best structures will be given to other schools for the same purpose (formality of the purpose of the construction, to take it seriously). The pupils express themselves, talk about their own experiences. The teacher explains that it is not a simple task; they will make many mistakes and they need to search well to get the best result possible. Having gotten across this idea, the teacher distributes the first part of the story, under the pretext that seeing and reading sources will give them more ideas for our goal. They read the title of the story and they make predictions for what they are going to read below.	At the end of the activity the pupils should: • Have grasped the problem in the issue posed (how best to the carry ice cream in the summer) • Start recalling ideas based on their experiences • Formulate predictions about the story, only by reading its title.
Introduction to the first part of the story 40 minutes	The teacher reads the first part of the story to the classroom (translating at the same time in sign language) and he/she stops at two points, * in order (a) to give the pupils opportunity to make predictions about what will happen in the next pages and (b) to express some primary feelings about the hero and the other characters of the story.	• Become emotionally closer to the characters of the story, criticize their actions and draw parallels with the problems they might encounter themselves when dealing the ice cream.
Chronological placement- Literature activity 5 minutes	The pupils will engage in a conversation with the purpose of recognizing that the life that is described in the story is in an older era and not in modern times. The teacher will initiate a discussion – make comparisons between our technology-rich lives and life in a village prior to rapid technical development. Using the story, the pupils are expected to provide different answers to the ongoing challenge of keeping things cold, such as the fact that earlier generations of people used to carry water in leather sacks made from animal skins. This comparison is useful because we want the pupils to realize that while the hero had fewer options and materials, he was still able to find the right materials to carry cold	• Learn how people in different periods of history have tried to keep things cold in transit and make a comparison with the present time in order to understand historical differences between various ways of food maintenance and get inspired to work on their own construction of a temperature-preservation device.

	water back to his village. It is hoped that the pupils will begin thinking of different materials, not only the ones that are presented in the text, but also contemporary ones. Furthermore, in this part I believe the teacher should problematize them by asking if they can think any ways that ancient people used to preserve food, when there were no fridges. For example, in Knossos, Crete they used to put the food in big earthenware jars and bury them under the surface of the earth.	
Brainstorming about the different materials Physics activity 5 minutes	Subsequently, the teacher asks the pupils: "If we wanted to carry the cold water, like the hero in the story, how would we do that since we have more options?". The purpose is to initiate a discussion so that the pupils can bring forward as many experiences from their daily lives with materials that preserve heat. The pupils are expected to provide answers like: "we will carry it in a plastic or glass bottle" or "we would put it in a flask or a thermos" or "we would put the cold water in a wine bottle and we would cover it with a cork". The teacher can problematize the pupils for their answers. For example: "Can we put the water in a metallic can?", "Is the plastic bottle enough to keep the water cold? Should we use something to cover it in order not to warm it up with our hands?" We expect that the kids will provide different opinions that are connected to their daily lives, thus bringing forward different perceptions/ misperceptions about materials that can conduct or not heat.	• Get a deeper grasp of the problem posed in the beginning and initiate a dialogue in order to develop a good argumentation for the solutions that they propose.
Group work 25 minutes	We give the pupils some time to discuss with each other on their teams and exchange ideas on how they will organize the construction process. The teacher provides to the pupils an extra piece of paper (I will make that), in which they can document their thoughts, their materials, the obstacles they encounter and a space to design their construction. During the children's discussions, the teacher will try to problematize the pupils about their answers, so that it is not easy for the pupils to reach a final conclusion. The teacher categorizes the ideas of the pupils and writes them on the board. This categorization has the purpose of helping children realizing how they think themselves about heat and thermal conductivity of materials in the scope of their everyday sociocultural environment. Every decision must lead to dead-end and going back to the story, they will realize that	• Realize that their current knowledge and ideas about solving the problem identify voids in their concepts, and that they hence need to learn more about heat and the thermal conductivity in order to find credible solutions.

	the hero reached also a dead-end; that is why he decided to explore more what is going on about heat and its conductivity. They need to see it firstly as a quest in finding out "what happens" rather than the engineering way "how I will fix it". Every group will have each own envelop where pupils can store their designs and papers with their thoughts, so that they can come back in every teaching session and look at their progress.	
Ending- Revision 5 minutes	The session is closing with the revision of the work that they did during the day and the conclusions that the pupils reach. There will be a discussion of the responsibilities that each pupil has and they will get organized for the next session. At the end the teacher will request from the pupils to search for any information that is relevant to their purpose and bring it to the class.	• Be able to summarize what they learn during the day.

*In the part where the teacher gives the opportunity to the pupils to make hypothesis and predictions and express their opinions, he/she can stop at the phrase: "His mother takes a sip happily but made a funny grin" and ask the pupils why Dimitri's mother made that grin in her face. We stop on purpose in that part and together with the pupils' predictions, we initiate a discussion for the role of Dimitri's mother in his life. For example, we can ask:

- What kind of grin do you think that Dimitri's mother did?
- What do you think about her reaction?
- What emotions do you have about her?
- How she should have reacted?
- Is there any support and encouragement? Who would we react if we were at Dimitri's mother place?
- How would we like to be treated by our parents during our effort to build the ice-cream carrier?
- How do we think Dimitris will respond next? How would you respond?

Next, we move on to the rest of the text and we stop at the phrase: "They burst to laughter". In this part, there is an introduction of more characters of the plot; Dimitri's friends. Their reaction to is effort was that they start laughing with him. Again, we stop and we initiate a discussion in order the pupils to empathize with Dimitris and understand better the message that the text is trying to convey. Different questions can be:

- How do you think Dimitris felt after this reaction of his friends? Did he give up? Continue trying? If we were at his place, how would we react?
- What is your opinion about their reaction? What does that show us about his friends? What should they do instead? How would we react if Dimitris was our friend? Have you ever laughed with your friends when they didn't succeed something in the first time?

Through this conversation, we have started shaping a psychological profile of the first characters that are close to the hero and influence his decisions. Dimitris wants the approval of his mother and friends, as sometimes we do with the people that are close to us. The criteria of choosing these two parts of the first part of the story is because it is obvious the stubbornness of the hero to succeed and learn how to be more effective in carrying the water. The pupils can see that behavior as an example for their own goal; Whatever the obstacles are or be discouraged by other people, we should not give up u goal and try to find solutions.

Second session

Activities	Description	Didactic goals
Presentation of the former session 5 min	The pupils discuss among each other the former session about and one of the groups is responsible to present in the class a summary of what they worked on the last time.	At the end of the activity the pupils should: • Recall as much information they can from the previous teaching
Analysis of the second part of the story 40 min	The teacher read and interprets the second part of the story, stopping again in 3 points** and asking the pupils to make predictions about what will happen next. At the end of the reading, a conversation can occur concerning their impressions and feelings about this part.	• Recognize the role that Lady Warmth, Sir Frost and Salamander play in Dimitri's problem. • Discover the relationship between Lady Warmth and Sir Frost and problematize on the riddle that they pose. • Connect Dimitri's experience to their problem to carry ice creams
Analysis of the details of the text and discussing possible clues. 2 min	The teacher asks the pupils: "When Dimitris entered the gold and silver door, his feet were too hot and too cold respectively. Why did he choose to wear shoes made from wool? Why didn't he felt his feet too hot or too cold after he putted on the woolen shoes?". The discussion that surrounds these questions is valuable because, according to the literature (Lewis and Linn,1994), many children mistakenly believe that the woolen fabric is a good conductor of heat or that wool "produces" warmth. In this case, after the pupils express their opinions, the teacher can provide the scientific opinion about wool.	• Recognize that the woolen fabric is an insulator.
The first experiment with the bowls. 8 min	After the discussion, the teacher poses this question based on what they read on the text: "We read that when Dimitris stepped in the cold, he felt a burning sensation on his feet. Why do you believe that happened?". It is very likely that the children to not know the answer to that question. This is why, it is proposed that we conduct an experiment using 3 bowls. The first bowl contains hot water, the second one normal temperature water and the last one very cold water. The pupils are supposed to put one hand in the hot water and the other one in the cold water. After 2 minutes, they put both hands in the normal temperature water. After the experiment, they describe what they felt when they put	• Experiment with the concepts "hot- cold" • Conclude from the conduct of the experiment that what we name "hot" and "cold" is relative to our particular physical state, so that our body (and hands) is not a precise measuring tool for determining what is "hot" or what is "cold". • Extend their thinking into how the results from the experiments can help with the materials for their device.

	the hands in the second bowl. They discuss the results from the experiment in the class and they can document their observations in the "experiment document" that I will provide. If it is not possible to realize that experiment in the class (due to practical reasons), then it is suggested that we show this video that the hero is doing the same thing: http://www.youtube.com/watch?v=Z5yF-SCVXq4 from 0.38 to 1.44. Due to their experience, the pupils can comment how our body can sense warmth and cold. The teacher can pose questions such as: What are we observing? Why do you feel like this when you put your hands in the second bowl? Why the one hand informs us that the water is cold and why the other informs us that the water is warm? After this discussion and after the pupils expressing their opinions about the original question, the teacher provides the scientific explanation by provide them with a small paragraph to read (or in case of difficulties in reading, the teacher can explain the phenomenon with the use of sign language).	
Group work 15 min	The children are discussing the things that they learned today and connect them with their construction and they make possible changes (e.g. add wool in their materials?). Children's opinions are documented and they put the new papers in their envelop.	• Connect all the information from the story and the experiments in order to change or add in their original design to make it more efficient.
Conclusions 2 min	At the end, they sum up what happened during the session. The children express their opinions and what impressed them and how what they did this day influenced their decisions on their constructions.	• Summarize all the information from the activities, and so be aware of the learning path that has led them to take specific decisions in relation to designing their device.

In this part, there is the option to add another experiment concerning how heat is conducted or show different videos with experiments and discuss the results. (for example:

https://www.youtube.com/watch?v=FLf4rZ3ULOI

https://www.youtube.com/watch?v=Bk5crxR7FrI
https://www.youtube.com/watch?v=KpqICpLKr0o (from 0.27 to 2.07)

Do you have any more or different experiments to propose?

**Furthermore, when they make the text analysis and the stop in 3 parts and make predictions, they can also initiate a discussion based on questions proposed. We can stop at the phrase: "But she stood

silent". In this part, there is an introduction of a new character "Lady Warmth". The questions proposed can be for example:

- Why "Lady Warmth" didn't give the answer right away to Dimitris? What is your opinion for this reaction?
- How would you characterize "Lady Warmth"?
- Which, do we think, will be Dimitris next reaction?
- How would we react if we don't get an answer right away?
- Would we like to have someone that gives us all the answers or should we look for them by themselves and formulate our own opinions?

The next phrase that the teacher stops is: "What did you come to me for? He replied and sent him away". Again, we meet a new character in the story, Sir Frost. Through focus questions we can achieve a connection with what the hero is facing and the problem that the pupils are dealing with. We can also highlight the relationship between Lady Warmth and Sir Frost. This is very important because children tend to conceptualize "hotness" and "coldness" are two different entities that are opposite to each other (as the hero does in the story as well) (Erickson, 1979). However, the message that the story wants to convey here is that Sir Cold and Lady Warmth are actually forms of the same energy that our body senses differently. That is why Sir Frost is describing Lady Warmth as her sister (same family) and that is why they are having the same behavioral patterns (speak with riddles, get angry when the hero demands for the answer). In the next part this will be more obvious as the hero cannot see anything from the two eyepieces that they give him at the same time. Some of the question that the teacher can pose and problematize the pupils about this part is:

- What is the connection between "Sir Frost" and "Lady Warmth"? Why are they behaving the same way?
- Why "Sir Frost" insists that they are not neighbors, but are family?
- Why they are not disagreeing or oppose to one another as Dimitris believes and instead they behave in almost the same way?

In the third pat that we stop, is the part that the salamander character is introduced with the form of help to the hero's problem and specifically they can stop at the point: "Warmth's riddle says again? "Different eyes you must have and mind, to see it."". In this piece we notice the help that the hero gets, after he already helped the salamander first. The purpose of this line of questioning is to highlights the importance of been critical and if we cannot solve something we can always look for some help. This is coming in parallel to what the pupils are doing compare to what the hero is doing. They both start a quest to solve a problem. Sometimes the problem can be hard and demanding, but they can use the help the get productively. The hero in the story gets the salamander, the pupils get this story. And, of course in every part that we stop there is a moral teaching involving; in this case, the hero helped the salamander and got helped by it. Some guidance questions that we may ask can be:

- Why did the salamander help the hero?
- What is the role of the salamander in the story?
- Did it actually tell him the final answer or did it just pushed him to think about the riddle again?
- How did he thank the salamander?
- What is "our salamander" in our quest?

In this point, they can have a general conversation about the things that they read in the story and discussed in the class, as well as the feelings and impressions that we got up to that part of the story.

Third Session

Activities	Description	Didactic goals
Review of the previous session 5 min	Review of the basic points of the two previous parts of the story and the physical concepts that they discussed through an oral presentation from one of the groups of pupils.	At the end of the activity, the pupils should: • Recall the basic information from the previous teaching

		sessions in order to be prepared for the introduction of the new knowledge
Analysis of the third part of the story 30 min	Then, the teacher hands out the rest of the story and reads it loudly signing at the same time. The teacher can stop in 2 parts and initiate a discussion about the things that they read. In this part, the story is introducing the mental model about the transfer of heat and it makes and analogy of thermal energy with warm girls and cold boys.	• Imagine the mental model of heat transportation with the boys and girls • Perceive Lady Warmth and Sir Frost as the same energy that our body senses differently
Reflection of the story as a whole. 10 min	A discussion can occur in the class on the whole story and let the children express their impressions and opinions about the text. They can compare their first impressions of the text with the ones after they finished reading (e.g. What is different with the hero's mother behavior in the beginning and at the end of the story?). The pupils can express their opinions about the ending of the story; if they expected to end like this and which ending they would choose.	• Compare their first and their final emotions in order to identify what has changed at the end of the story and why (it helps with the emotional connection with the story and the creation of empathy towards the hero) • Use their imagination to provide an alternative ending to the story (it helps with the literature development and the advancement of their creativity)
Transmission of heat by conduct- Representations with the model from the story. 30 min	An evaluation of the progress of construction can occur. In order to connect their construction process with the story, the teacher can initiate a discussion in order to problematize the pupils using as a starting point the model that they read in the story. Some questions proposed can be: - What do you think are those boys and girls? Why do they move around and go in and out the water all the time and they just don't stay stable? Where can we find those? - What was the usage of the eyeglasses that Dimitris got? If we had those glasses, what would we see in the classroom? What will we see when we put the ice creams in our construction? Through this discussion, the pupils will problematize for their own constriction; what materials are keeping the "girls" out of their device and if they need to cover it with any material (like the hero that covered the sack with woolen pieces). Then they can discuss about the factor that can melt the ice creams in	• Use the mental model with the little girls to explain the heat transportation. • Document the agents that make the ice cream melt. • Represent the model with the little girls with educational materials and/ or computer for better visualization of heat transportation.

	the summer. The teacher, for example, can ask: "what was the factors that made Crystal Water warm?" and then urge them to think "What are the factors that will melt our ice creams?" Some possible answers that the pupils may give are that the ice creams are melting because of the sun or the hot air in the atmosphere or our hands can warm it up when we touch the device. We should problematize pupils how we can prevent those factors from melting the ice creams, "What should we do?". First of all, in order the pupils to decide what they should do, they need to understand deeply what is going on and how the model works. For this reason, they can make a representation how the "girls" are moving to their ice creams using red play-do. The pupils can make different representations of the "girls", which can be photographed from the teacher. Alternatively, they can use colors (e.g. color how they picture the girls to move from our hands to a bottle with water when we hold it) or they can color it in the computers using the "Paint" application of Windows. They can use the representation to explain different phenomena (e.g. what happens when we touch a metallic pot compared to when we touch a wooden surface or what happens with the "girls" when we touch an ice tube with our bear hand and when we wear gloves). We choose to use the model on the "girl" side and not the "boy" side because scientifically, we choose to explain the transmission of heat from the view of how energy helps the molecules move faster and not how slow the molecules are moving. We leave the pupils discuss and think how we can prevent "girls" from melting the ice creams. Their ideas and answers are documented in the document that I will provide to the teacher. The teacher is trying to question pupil's answers, so that they can argue better for their choices.	
The role of the color 5 min	Next, we move to the choice of the color. Is color important to our construction? The teacher can show this video (http://www.youtube.com/watch?v=Xd-rtTdp4_c) and let the children comment on the role of the color or he/she can provide them a small paragraph from the book explaining the connection of black and white with heat transmission. As we can see in the video, pupils should deduct that the dark surfaces absorb "girls" more easily than the white ones, which is an important information that can	• Explain the role of colour in the absorption of heat from different materials.

	help the efficiency of their devices. At the end, it is good to distinguish the transmission of heat in two categories: Transmission from touching (e.g. our hands that conduct heat to the ice creams) and transmission of heat from distance (like the sun). Some of the pupils may cover their device with aluminum foil to reflect the light and prevent from heating like in thermos cups (of course that requires that the pupils have been taught the characteristics of light).	
Group-work 10 min	After these activities, the pupils are discussing with their group and make final decisions in their construction, taking into consideration all the information they encountered.	• Implement the model with the little girls to explain the materials they have chosen for their device. • Choose carefully the materials they need for their final construction work, combining their experience with knowledge they obtained and the discussion among each other, • Be capable of justifying their choices.
Review 2 min	In the conclusion, they can make a summary of they worked on today, what messages did the story gave them, how they feel about it and what they are going to do in the next session. The teacher can prepare the pupils and inform them that in the next session they need to be ready to start building the device. Therefore, if they need to bring more materials (that are not included in the original ones that I will provide), they need to do so in the next session.	• Summarize the conclusions they have reached from the story and the visualization of the model. • Prepare the materials in order to be ready to start constructing the next time

*** In this part of the story we stop again in two parts trying to help pupils reflect on the story and on the messages that provides. They first stop at the phrase: "This is it!". This is the part, where the hero after trying the eyeglasses and sees the "energy", understands how to transfer the water back to his village. This is an important part as they will use this model (with the little girls) throughout the next sessions. Some questions that can prove helpful in fully understanding the model can be:

- What does Dimitris see when he puts on the red eyepiece? What does he see when he wears the blue eyepiece?
- Why Dimitris can't see anything when he put the glasses together? (in order to answer this the teacher can remind them the previous set of questions, when they answered why Sir Frost and Lady Warmth have almost the same behavior. The important thing is to help pupils capture that Sir Frost and Lady Warmth is the same "person", as thermal energy is one, but our body understands it in different ways. Therefore, the right answer (scientifically) to this question is that he cannot see both girls and boys, because we can describe the transfer of heat either by the fast movement of molecules (girls) or the slow movement of molecules (boys). There cannot be a coexistence of the two explanations.)
- How did the water get warmer?

- What solution did he find to keep the “girls” from entering his sack?
- Do you think he made it? Will the water stay cold?

The next part that is suggested to stop is: “He poured her a glass”. At that point, we wait to see the reaction of Dimitri’s mother for the second time. The questions we can pose are:

- Do you think that Dimitris made it? How do we expect the mother to react?

-If he didn’t manage to bring the water cold, how should she react?

-Is it important for us to work hard to achieve our goals? How important is to work hard to achieve things in our lives?

Fourth session

Activities	Description	Didactic goals
Review of the previous sessions. 5 min	Firstly, the children are discussing in their groups about what happened in the previous sessions. After 2 minutes, one of the group is responsible to describe what they discussed in the whole class. They describe shortly what they read in the story	At the end of the activity the pupils should: • Recall all the important point from the previous sessions, including the story and the mental model in order to ease the introduction of the new knowledge.
Usage of the model with “girls” in the experiments 15 min	Before the construction, the pupils can try to explain the experiments that they did (or watched) with the help of the model with the “girls” that they saw on the story in order to distinguish better the good from the bad conductors. In this part, the terms “conductor” and “insulator” (these two terms are not so obvious to distinct in Greek language because they are words that are coming from the ancient Greek language) can be explained by imagining how “easy” or “difficult” can “little girls” pass through them.	• Explain the experiments with the aid of the mental model with the girls • Distinguish the physical concepts of “conductor” and “insulator” • Distinguish that the heat can be transferred more easily in certain materials and more difficult in other.
Building of their device 50 min	Time is given to the pupils to build their device with the material that I will provide or the material they chose to bring.	• Engage actively in the device creation creating a carrying box covered with isolation materials
Presentations 20 min	Each group makes a short presentation of their process and they argue for the materials they chose. The teacher and the other groups pose questions concerning how easy or difficult can “girls” pass by their devices.	• Justify and argument for their choices of the materials that they used (helps in the development of critical thinking, argumentation and presentation skills) • Pose questions to their classmates and express opinions based on critical thinking

Fifth session:

Activities	Description	Didactic goals

Review of the previous sessions. 2 min	The teacher asks the pupils to give a short description of what they did in the last sessions in order to bring back the clues from the stories and the feedback from the presentations.	At the end of the activity the pupils should: • Recall all the important information of the previous sessions
Problematization about making handles 5 min	There can be a 5 min discussion in the class concerning how the kids will touch the device when they carry the ice creams. If the teams have not already thought about putting handles in their devices, then this is the time where we can initiate a discussion about how "girls" are moving from our hands when we are touching different objects. Therefore, not only pupils will start thinking about the handles, but from what materials should they build them. The building process and the actual devices can be photographed from the teacher.	• Realize that the heat transportation occurs through conduct, currents and radiation and find ways of dealing with them in their construction. • Make final changes in their devices based on the feedback the received in the presentation
Experiment of efficiency of their devices. 50 min	The pupils brainstorm with different ways that they can check for the efficiency of their devices. They can put ice cubes instead of ice creams and they place them inside the device. They count how much the ice cubes melted with the usage of a tube in order to determine which device is more efficient. In the meantime, pupils can work individually in writing their own short story around their own experience from their problem using as heroes themselves, their classmates, their teacher and maybe Dimitris.	• Discover experimentally which device is more efficient and why • Engage in the creation of their own story based on their experience.
Questioning: same materials from carrying hot and cold objects? 8 min	Finally, the teacher problematizes the pupils in the class by saying that he/she wants to use their device to carry warm food instead of ice creams. The pupils can express their opinions about that statement. After this discussion, the teacher can provide the scientific explanation about this question.	• Understand that insulation helps in the maintenance of heat and it is independent if we feel something to be cold or hot.
Conclusion (Metacognition activity)	The teacher asks from the pupils to compare the new ideas that they have now with the old ones that he wrote on the board in the first session, as well as the difficulties they encountered in the process. The goal here is the pupils to realize their learning process. In this part the pupils make an effort to distinguish the everyday from the scientific thinking. At the end, they decide where they can put their devices until summer.	• Participate in a metacognitive procedure in order to try to realize their learning process • Distinguish the scientific from the simple way of thinking.

Notes

Moreover, we can create a "project corner". We use a corner of the classroom and we put two desks together, where the children can leave their devices and materials. I will also bring a big foamy board where the pupils can pin different information they find from books or from the internet (e.g. find information on how a fridge is made). In some cases, the teacher can also pin some extra information that he/she thinks are valuable for the class. I can also send to the teacher information to pin them up for the pupils to see.

The approximate minutes that are given are only a suggestion. When I visit the schools, we will arrange how the teacher would like the time to be divided, according of course to the pupil's capabilities and needs. In the curriculum there is no suggestion about how long should last the teaching of the "Heat and Conductivity" chapter in Physics. However, in the general education curriculum, this chapter is suggested to be taught in 7 hours. Since they have almost the same curriculum and the same books, I presume the project can be taught in 7-10 hours depending on the level of the class and the time that teachers can devote to this project.

The plans were based on the project teaching method. As it can be observed there is both literature analysis of the story and scientific analysis. There are activities that have historic (e.g. the chronological placement activity), artistic, folkloric, experimental and learning-by doing context. It is also a problem-based teaching method, because since the beginning of the sessions, the children have a problem (how to carry the ice creams cold) and they are expected to provide a solution at the end of the classes. Since it is a project, the "project corner" is suggested to the teacher to help both the pupils themselves and the teacher to organize the classroom space. However, due to the limited number of children in each class, there seem to be pointless to assign roles in every pupil in the group.

There is also another idea of how to open and close the sessions. Instead of the headmaster coming and asking children to build the ice cream carriers, we can present it as an entering to a "competition". We can tell pupils that their devices will be send to Sweden for research purposes and that other Greek deaf schools are also participating. At the end, I can send to the school, in a sealed official envelop, the "completion results" together with a piece of paper for each pupil that thanks them for their participation.

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Appendix 6: The story

The freshest of waters

Stelios Pelasgos & Vasilis Kollias

Once upon a time, there was a young lad called Dimitris, bright at heart and full of ideas. He lived in a prairie beside a giant mountain and had an uncle who was a shepherd. This uncle of his had spoken of the waters of the crystal springs. Hidden within the mountain, at the edge of a razor-sharp gorge that ran from the peak. Up there was a giant piece of eternally frozen ice. A small glacier. The shade of the deep gorge sheltered it from the sun, so that only on the warmest of days, from St. Elias day till the day of the Cross a little part of it was melting. It was then that the thawed glacier joined the waters of the springs, and the folk would say that the waters of the Crystal Springs was the coolest water all year long.

Every summer this young lad would yearn the water when the summer heat was the hottest and upon growing up, he decided to bring it to his village. With the blessings of his mother he took off.

- I shall bring you some as well, mother, to taste this crystal water, he promised with pride.

Dimitris had with him a small woolen satchel, and put in a small blade, some crackers and olives for a small meal and a spool of thick wire. He also took a small sack to fill it with water, and climbed towards the springs, remembering his uncle's suggestions. He found the springs at the lowest reach of the gorge, which resembled a shallow open cave. He quenched his thirst with the water, cooling his insides. He was sweating, his skin had dried up from the sun but his mouth, throat and innards almost froze and he felt being filled with otherworldly powers that could let him open his arms like wings and fly through the cool breezes of the mountain, looking at his village in the prairie, roasting in the summer heat. Truly, this water was entirely different from what the villagers had been drinking.

Once he returned to the village with the sack full of water, he found his mother which had gathered the neighbors to try out the revered Crystal Water.

- Drink some, mother, said Dimitris

His mother takes a sip happily but made a funny grin.

- This is warm like in our village my son, she told him, warmer even than the one we keep in our kitchen.

He takes a sip. This was not the same he had tried up there on the mountain. Filled with shame he was, and his mother too, for she had boasted about him to her neighbors for her son's virtues.

Stubbornly, Dimitris turned to his mother:

- If I bring more of it, it will heat up slower and shall stay fresh and cool. Bring your friends and have them wait for me.

He grabbed a great can, climbed back up, drank some and filled the can with water. He then held the can on his back and felt a strong chilling sensation. But he knew no pain, neither from frost nor from heat.

-It cannot be. For the can to be so cold and my back feeling the chill, it should stay fresh and cool, he thought to himself.

With haste, he sprinted downwards without giving in to the cold until he stopped noticing it. He returned as fast as he could, his feet becoming hot within his shoes- but how quicker could he be, bearing such a weight?

His friends awaited him at his front yard, to taste the Crystal Water.

They take a sip. Warm as the water of their village.

They burst to laughter. The lad was saddened and became even more stubborn. How could he bring this water from the mountain without it becoming warm on his way back?

The next day he took the satchel with the blade, the wire and his food, grabbed the sack, because he was determined to find some way of bringing the water back to the village, no matter how much it would take.

He arrived at the spring and noticed a small crevice that lead to the insides of the mountain.

- A cave, he thought. I shall explore it. Maybe I will discover the springs' origin, where the real crystal water resides, that does not spoil on the way back home.

Alas! He was afraid to enter it because the crevice was too narrow, and images of bats hanging from the ceiling started filling up his mind!

Finally, he takes a deep breath and steps into the darkness.

Surely, he said, this is where I shall find the real Crystal Water.

The entrance was narrow, and one had to step onto the water. The lad takes off his shoes and socks and plunges into the water. Brrr! Extraordinarily cold – crystal!

Further inside the cave started to widen but the light was fading all the more. He advanced towards the void as much as he had the will and right at the moment when he was about to give up and return, he caught a shimmering light. He looks curiously. And he saw it, right there. Two doors. Glowing. One of them in bright and golden, the other one faint and silver. Between them, at a great height, poured the water down the cave's walls, forming a small stream at the feet of the two doors.

- This is rather peculiar, he mumbled to himself. What are two doors doing here in a hidden cave. The waters here might be spellbound.

He was not a coward; we have said that already. Other youngsters of his age would have fled immediately. But not him… Dimitris stared at the door that had a carving of the Sun on it. With a light push, he enters it.

He was met with a dazzling light and shut his eyes closed. His bare feet became very warm. He looked around him. He found himself in a warm place, it was summer all over. Wherever he turned to, he could only witness an endless prairie with golden soils, roasted by the sunlight. Further away he saw a cabin with dried straw. He goes on to knock on its door. The door opens and out of it came out a young lady with golden hair and tanned skin.

- Who are you?
- I am Dimitris, who are you?
- I am Warmth, what is it you want?
- I am looking for the water of the Crystal Springs.
- It is the cave's water.
- It just will not keep fresh until I return to my village.
- But of course. You must find a way for me not to heat it up, she replied with a mocking laugh.
- How?
- Solve my riddle and you shall find out, she said and went on:
- "Same it stays, it comes and goes

Same is hot and cold

Different eyes you must have

and mind, to see it."

Dimitris was staring, waiting for her to say something more. But she stood silent.

Dimitris could not understand a thing.

- Give me some help, he pleaded her.

Warmth gave him a nonchalant look.

- Let the river take it (I give up, tell me the answer), insisted Dimitris.

-Which river? She asked. The river of the crystal water? Go on and ask it then, she remarked furiously.

He left the cabin but as he trailed back to the door the warm soil became hot. Near the end the lad started skipping as we do on the broiling sands during a summer day. He returned to the shade of the straw cabin. He had no intention of having his feet scorched because of lady Warmth's anger. He should not have left his shoes back then to tread through the chilling river in the cave. But how could he have known what was to follow?

His mind was fleeting however, constantly drawing plans and ideas.

- So, this is how you want it to be, lady Warmth?

He reaches for his blade and cuts his woolen satchel evenly. He then snaps two pieces of wire, wraps the pieces of wool around his feet and ties them with the wires. He easily walked to the golden door - the heat could not reach him through the wool. He passes through the door and finds himself in the darkness of the cave once more. Beside him ran the springs' stream. When his eyes adjusted back to the darkness, he saw the silver door on the other side. There was a carving of the moon on it. He removes the woolen makeshift shoes but hangs on to them. He hangs them around his neck and enters the door of the moon.

He arrived at a place filled with snow. Wherever he turned he would only witness endless miles of white. His feet started to burn from the ice-cold snow he was standing on.

- What is happening? He thought. My feet are burning just like before when I was stepping on the hot soils of the land of lady Warmth.

He need not think a lot, he had the answer. He once again wore his makeshift shoes made of his satchel and advances. Further down he noticed a cabin made of ice pillars. He knocks on the wooden door of the cabin, wooden just like the hay cabin.

The door opens and this time a young lad is seen standing, with white hair and a pale face.

- Who are you? He asked him with a crackling voice, crackling as the ice cubes crackle when thrown in a quenching lemonade during the summer.
- I am Dimitris. Who are you?
- I am Frost. What is it you seek?
- I am trying to find the crystal water.
- It is the cave's spring water
- It just does not stay fresh. It spoils on my way back.
- You shall find a way to keep it fresh.
- Well, this is what I am looking for, sir. How?
- Listen to the riddle and you may have your question answered.
- "Same it stays, it comes and goes

Same is hot and cold

Different eyes you must have

and mind, to see it."

- Oh, not this again, you are not the first to tell me this.
- Who else told you then?
- Your neighbor, lady Warmth.
- She is not my neighbor, she is my sister.
- So, you have conspired to tell me the same to mock me? I know that warmth is the opposite to cold and that you should be at odds with each other, arguing all the time and disagreeing with each other. You are driving me into madness, I cannot find the answer to your riddle.
- Let the river take it (I give up, tell me the answer), said Dimitris.
- Go on and ask the river, young one, he replied coldly (chillingly that is because his mere voice was ice cold already). What did you come to me for? He replied and sent him away.

Dimitris walked through the snow boiling with anger and confused until he exited through the silver door. After going through the door, he sat on a boulder near the water. He took off his shoes and washed his feet, which started to feel tickly as they rubbed against the coarse wool of the satchel.

He then took out his crackers and olives and started eating, with the dim light coming from the glowing doors illuminating his surroundings. He could not solve the riddle with an empty stomach.

Suddenly he sees one of the rarest animals he had ever seen in a book or photograph, beside his feet. A white cave salamander. It was creeping slowly and its moist skin was glowing. He threw some crumbs from his crackers and was watching it as the salamander was searching for them with its tiny feet that looked like miniscule human palms.

The salamander opened its mouth and recited:

- "Same it stays, it comes and goes

Same is hot and cold

Different eyes you must have

and mind, to see it."

Dimitris was left dumbfounded and speechless...

- I did not ask for food yet you fed me

Now it is my turn to help you

Within the darkness my ancestors and I

Spend the whole of our lives

The first of our kind that entered the cave

had eyes to see but no wits to talk

For the new eyes you are seeking

Go back at the beginning of the riddle.

Within the cave the eyes are useless

But yours do not even suffice.

A blind salamander that talks with rhymes and gives out advice!

Dimitris was astonished. He tried to understand its words while leaving more crumbs as a thank you.

"Go back at the beginning of the riddle" and "Your eyes do not even suffice". What did lady Warmth's riddle say again? "Different eyes you must have and mind, to see it.".

- That's it! I have to return to lady Warmth at the start of the riddle.

He hesitated a little, thinking of the hot soil that had burned him on his attempt to leave the cabin. Maybe he was burning up the whole time and this time she would spoil his shoes that he handcrafted?

Oh well. No pain no gain. He stood up and enters the golden door once more. Thankfully, it is not hotter than before. The young lad rushes towards lady Warmth's cabin.

- Lady Warmth, he yelled. I figured it out. Please give me a new set of eyes to change my mind so I can finally understand.

Lady Warmth opened the door, looked at him with a smile and handed him half a pair of glasses with a red frame.

Dimitris was puzzled but thanked her without complaint.

He then rushes to sir Frost and….

- Sir Frost, he yelled. I have figured it out. Please hand me a new set of eyes to change my mind so I can finally understand.

Sir Frost let him inside and lead him to a room, where, among a pile of tools he reached for another half a pair of glasses with a cyan frame and gave it to Dimitris.

When he found himself in the cave chamber with the two doors, he took off his woolen shoes and left them at the rock. He entered the narrow river and treaded his way out from the cave.

Suddenly he slipped and fell, hitting his hand. He stood up once more and attempted to continue. But he slipped again on the slippery moist rocks.

It seemed that the cave would not permit him leave, not letting its secrets wander into the light of the sun outside. The lad stayed there for long, rubbing his injured knees.

The voice of the white salamander, that had climbed the watery boulders next to him, came as an answer:

- I, who reside in both and land and water

gave you the secret but you have yet to get the meaning

Whatever once helped you

Now has slipped your mind

You get rid of it without second thoughts

But in time you will come to its need

Honor every help and say thank you

Because you alone shall never bear the water

He came to know his mistake. He thanked the salamander and left her his remaining crackers.

He returned and retrieved the pieces of the woolen satchel he had thrown away.

He then once more turned towards the exit and a little later he had exited the cave. He sat under the sunlight to dry up and warm up.

He took out the two halves of eyeglasses.

They each had an indent in the middle and could be stuck together. He joined them and wore them. He took a look at the small river. However, his vision was flooded by stupefying and dazing colors. He then split the glasses and wore one piece at a time. And something astonishing appeared before him.

When he wore the cyan eyepiece on one eye and looked through it. He witnessed there, within the waters, a mass of tiny azure boys that resembled sir Frost somewhat. Those who were deep in the river drifted with the water. But the ones that were near the surface, came out of the water eventually. As soon as they stuck their heads and hands out of the water, a light blue balloon started forming from the tips of their fingers. The balloon was taking them up high and scattered them around.

He then put the blue spectacle back in his pocket and reached for the eyepiece with the scarlet frame. Holding his other eye shut, he searched for the tiny boys within the waters. Instead he realized he was looking at some small girls that looked like lady Warmth. But the air around him was full of them! Once they touched the surface of the running water, their skirts would spread into small boats and rafts. With their feet within the waters, their body outside, they would float for a little before diving in to swim around. But the water would sway them.

Dimitris started looking around him, switching his eyepieces. And depending on the eyepiece, he would keep seeing either the boys or the girls. But once he joined the pieces together he could see neither. Only a mix of scarlet and blue haze that would stun him. Neither cold nor warmth.

- The is something happening here, he thought to himself. The water is getting warmed up because the golden lady Warmth look-alikes keep getting inside. I have to stop them from entering!
- But still, if the little boys that look like sir Frost keep getting out, would it not still get warm?

The riddle echoed in his mind: “Same is heat and cold”.

They either enter or leave

but the water they still heat.

But why is it together I cannot see them?

-This is getting out of hand, I am losing my mind and have started thinking in petty rhymes.

He filled his sack with water and took a look at it with his red eyepiece. There they were, those little girls kept finding their way in! With the light blue eyepiece, he once again saw the little boys leaving the water.

He then remembered the white salamander:

“You get rid of it without second thoughts

But in time you will come to its need”

He took the two pieces of cloth that were lying next to him, drying under the hot sun.

- These protected me against both the scorching soil of lady Warmth and her brother’s frozen snow.

He wrapped the sack with the woolen pieces and then took a look through the red eyepiece. The golden tiny girls were struggling to get inside. And now with the blue eyepiece. The little ones barely made it out.

This is it!

He emptied out the sack, wrapped it with the cloth pieces and tied them well with the wire. Afterwards he filled it up again with the crystal water from the springs and ran like the wind back to the village. He arrived just as his mother was sipping on her afternoon coffee in their yard, under the mulberry tree.

- Here you go mother. Water from the mountain, crystal clear and fresh.

He poured her a glass.

Bless you my son, may you have its freshness (may it quench your thirst-phrase/toast). You made it.

He went out and called all his friends, who were riding along the road on their bicycles.

They came to him, exhausted and sweating, and thus he served them some of the mountain’s water. And they cheered!

Never forget! All the cool ice cream that is made in Dimitris’ village even to this day, has its roots in this story. With his invention many would venture towards the mountain with mules and bring back pieces of the glacier from the peak and afterwards making ice cream for weddings and christenings.

If you ever get invited to a wedding in this fine village, you should definitely go. You will taste the best traditional ice-cream.

Appendix 7: The group supporting documents for the pupils' design

Observation Paper

The observation paper is to help you with the experiments that are going to take place in class and is a good tool for remembering all you have seen which will help you on your creation!

Experiments

Experiment with the bowl: How well can my hands measure the temperature? Do I need something else? Why can't my hands agree on it and feel different every time?

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Experiment with the balloons

Assumptions I'm making BEFORE the experiment (What is going to happen to the balloon?):
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What did we observe? What happened to the balloon?
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Experiment Sheet

5th lesson session

Description and Results from the experiment with my craft.

Which craft can keep the ice-cream from melting the longest? Why is this craft better for carrying the ice-cream? What happens to the little girls when we put in the ice cubes? Why are the ice cubes melting?

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Water that has melted

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Craft Sheet

Team Name

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Team member names:

1)……..

2)……..

3)……...

4)……

1. What materials am I going to use for my craft?

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2. Team proposals for the craft

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3. Making a sketch of my craft

Appendix 8: Completed worksheets and extra material adjustments from every school

Original

School A:

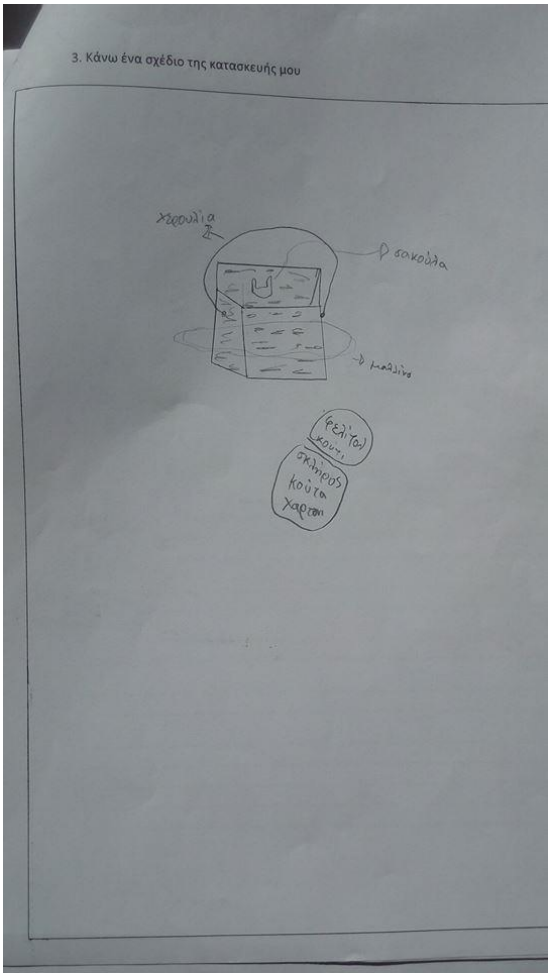


Image 1 (Box design)

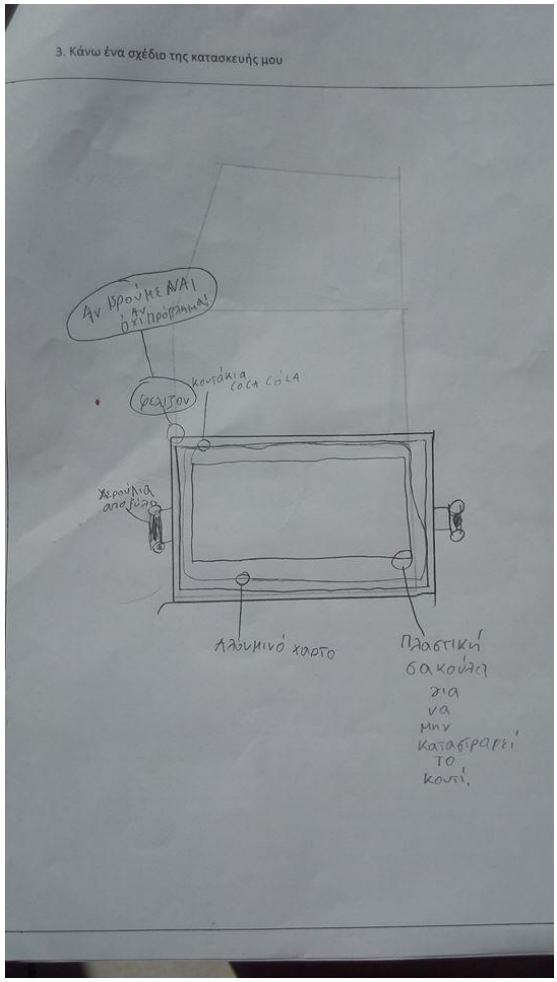
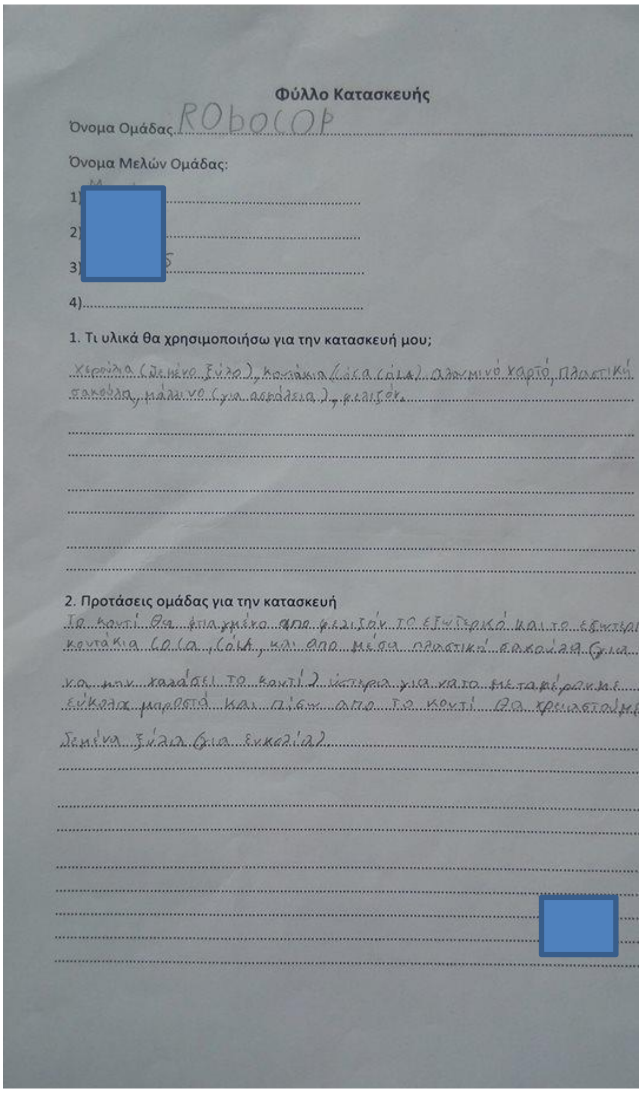


Image 2 (box design)

Image 3 (design description)


Φύλλο Κατασκευής

Όνομα Ομάδας ROboCOP

Όνομα Μελών Ομάδας:

[redacted]

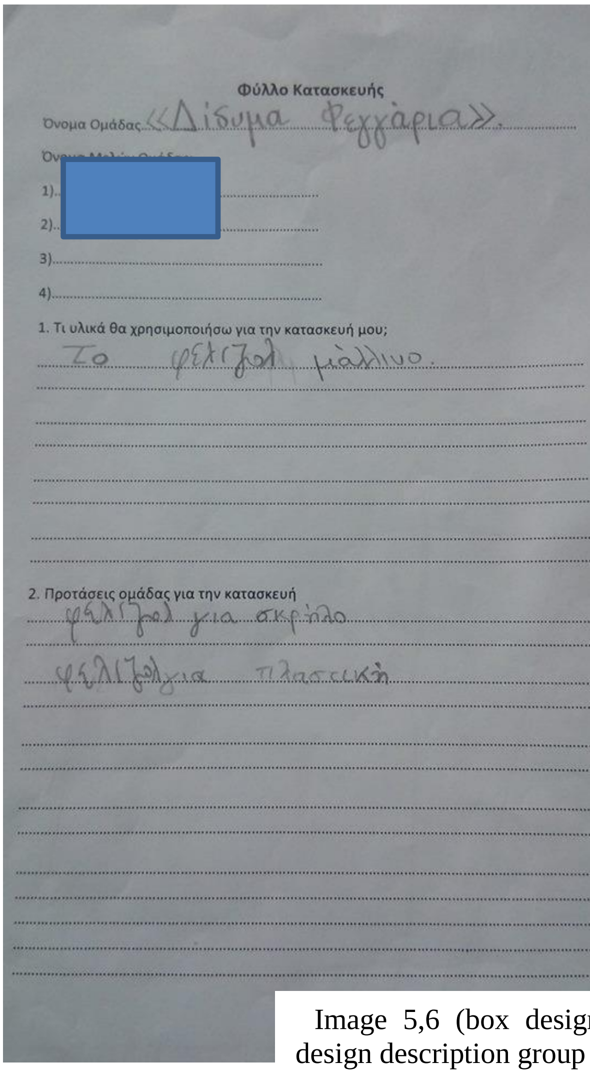
4)

1. Τι υλικά θα χρησιμοποιήσω για την κατασκευή μου;

2. Προτάσεις ομάδας για την κατασκευή

[redacted]

Image 4 (design description)


Φύλλο Κατασκευής

Όνομα Ομάδας «Δίδυμα Φεγγάρια».

[redacted]

3)

4)

1. Τι υλικά θα χρησιμοποιήσω για την κατασκευή μου;

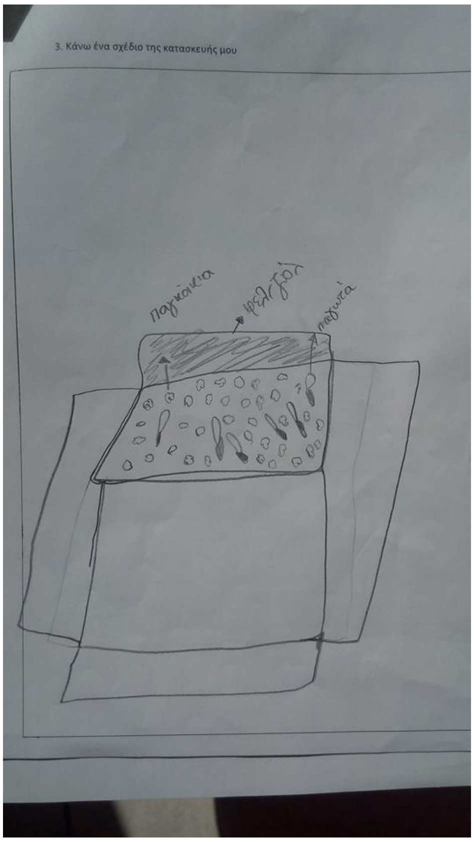
Το φελιζόλ μάλλινο.

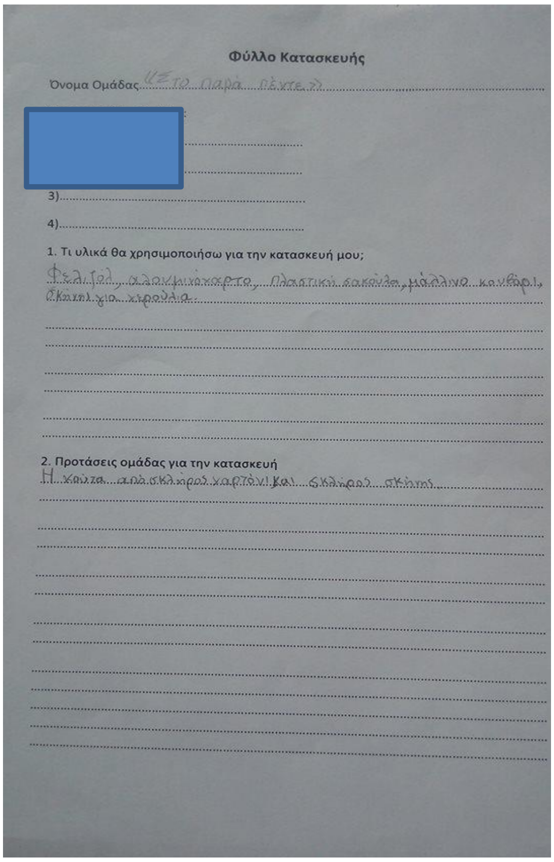
2. Προτάσεις ομάδας για την κατασκευή

φελιζόλ για σκρήπο

φελιζόλ για πλαστική

Image 5,6 (box design and design description group 3)




Φύλλο Κατασκευής

Όνομα Ομάδας «Ξ το παρά πέντε»

[redacted]

3)

4)

1. Τι υλικά θα χρησιμοποιήσω για την κατασκευή μου;

Φελιζόλ, αλουμινόχαρτο, πλαστική σακούλα, μάλλινο κουβάρι, σκοινί για χερούλια.

2. Προτάσεις ομάδας για την κατασκευή

Η κούτα από σκληρό χαρτόνι και σκληρό σκοινί.

School B:

Το δροσερό νερό

ιρό, ήταν ο Δημήτρης. Ο Δημήτρης ήταν ένα έξυπνο παιδί και είχε συνέχεια ιδέες. Ο Δημήτρης ζούσε σ' ένα χωριό δίπλα σε ένα ψηλό βουνό. Ο Δημήτρης είχε έναν θείο. Μια μέρα ο θείος του Δημήτρη, είπε:

- Θα σου πω ένα μυστικό! Μακριά στο βουνό, υπάρχει μια πηγή. Αυτή η πηγή έχει δροσερό νερό.

- Με ποιόν τρόπο το νερό της πηγής είναι δροσερό; Εμείς στο χωριό, δεν έχουμε δροσερό νερό.

-Επάνω στο βουνό υπάρχει ένα μεγάλο κομμάτι χιόνι. Το χιόνι λιώνει σιγά-σιγά και ενώνεται με το νερό της πηγής. Με αυτόν τον τρόπο, το νερό της πηγής είναι το πιο δροσερό νερό.

Όταν ο μικρός Δημήτρης μεγάλωσε, αποφάσισε να πάει στην πηγή και να φέρει το δροσερό νερό στο χωριό.

- Θα φέρω το δροσερό νερό και θα δοκιμάσει όλο το χωριό!Το υπόσχομαι! Είπε στη μητέρα του ο Δημήτρης.

- Εύχομαι να τα καταφέρεις, καλό μου παιδί. Είπε η μητέρα.

Ο Δημήτρης πήρε μαζί του μια μάλλινη τσάντα.Μέσα στην τσάντα έβαλε ένα μαχαίρι, ψωμί και ελιές για να φάει και ένα χοντρό σχοινί. Ακόμα πήρε ένα σάκο. <<*Μέσα στο σάκο θα βάλω το νερό*>> σκέφτηκε ο Δημήτρης.

Ο Δημήτρης ξεκίνησε το ταξίδι του και ήλπιζε να τα καταφέρει. Περπάτησε αρκετά και βρήκε την πηγή μέσα στη σπηλιά. Ήπιε και απόλαυσε το νερό. Ο Θείος του είχε δίκιο. Αυτό το νερό ήταν διαφορετικό από το νερό του χωριού.

Ο Δημήτρης γύρισε στο χωριό και πρόσφερε το νερό στη μητέρα του και στις φίλες της.

- Πιες μάνα, λέει ο Δημήτρης

Πίνει η μάνα του αλλά έκανε μια γκριμάτσα.

- Ζεστό είναι παιδί μου! Αυτό το νερό μοιάζει με το νερό του χωριού μας.

Ο Δημήτρης δοκίμασε.. Η μητέρα του είχε δίκιο. Ο Δημήτρης ένιωσε ντροπή και και πολύ λυπημένος.

Ερωτήσεις

1. Τι γκριμάτσα πιστεύεις ότι έκανε η μητέρα του Δημήτρη; (Δείχνω τη γκριμάτσα)
2. Η συμπεριφορά της μητέρας ήταν σωστή;
3. Πώς ένιωσε ο Δημήτρης;

2. Η συμπεριφορά της μητέρας δεν ήταν σωστή. Αυτή έκανε μια χαριμάτσα και είπε: Το νερό δεν είναι δροσερό. Αυτό είναι ζεστό. Το νερό μοιάζει με το νερό του Χωριού. Η μητέρα έπρεπε να πει: Δεν πειράζει! Την επόμενη φορά θα τα καταφέρεις.

3. Ο Δημήτρης ένιωσε λύπημένος. Αυτός λυπήθηκε.

Το δροσερό νερό *(συνέχεια)*

Ο Δημήτρης λυπήθηκε αλλά πείσμωσε! Εγώ θα τα καταφέρω!*είπε.*

<< Αν βάλω περισσότερο νερό μέσα στο βαρέλι, το νερό θα αργήσει να γίνει ζεστό >> *σκέφτηκε.*

Νωρίς το πρωί, ο Δημήτρης πήρε ένα μεγάλο μεταλλικό βαρέλι και ξεκίνησε να πάει στην πηγή. Λίγο πριν το μεσημέρι, έφτασε στην πηγή. Γέμισε το μεταλλικό βαρέλι με το δροσερό νερό, έβαλε το βαρέλι στην πλάτη του και γύρισε στο χωριό.

Οι φίλοι του Δημήτρη περίμεναν στην αυλή. Αυτοί ήταν ανυπόμονοι. Περίμεναν να πιούν το δροσερό νερό. Όταν ο Δημήτρης έφτασε και πρόσφερε το δροσερό νερό... Το νερό ήταν πάλι ζεστό..

Ο Δημήτρης πείσμωσε ακόμα περισσότερο. Αυτός πήγε πάλι την πηγή. Ξαφνικά, πίσω από την πηγή είδε μια σπηλιά. Η σπηλιά είχε νυχτερίδες. Ο Δημήτρης δεν φοβήθηκε καθόλου. Πήρε μια βαθιά ανάσα και μπήκε στη σπηλιά.

Περπάτησε και είδε δύο πόρτες. Η μία πόρτα ήταν κίτρινη και η άλλη πόρτα ήταν γκρι. Ανάμεσα στις πόρτες έτρεχειτο δροσερό νερό. Ο Δημήτρης σπρώχνει την κίτρινη πόρτα και μπαίνει μέσα...

Ερωτήσεις

1. Ο Δημήτρης ζει σε χωριό ή πόλη;
2. Η ιστορία του Δημήτρη συμβαίνει πριν τρία χρόνια ή πριν περισσότερα χρόνια;
3. Η ζωή στο χωριό είναι εύκολη;
4. Εσύ έχεις θάρρος να μπεις στη σπηλιά;
5. Σκέφτεσαι και δίνεις μια συμβουλή στο Δημήτρη. Με ποιόν τρόπο μπορεί να μεταφέρει το δροσερό νερό (για να) μην γίνει ζεστό; :

ιδέες
Πλαστικό μπουκάλι
Τυλίγω το μπουκάλι με χαρτί

1.) Ο Δημήτρης ζει σε χωριό.

2.) Ο Δημήτρης ζούσε πριν πολλά χρόνια. Ο Δημήτρης δε ζει τώρα. Ο Δημήτρης ζούσε πριν περισσότερα χρόνια γιατί: α) Δεν είχε αυτοκίνητο να πάει στην πηγή β) Δεν είχε ψυγείο να βάλει το νερό.

3.) Η ζωή στο χωριό δεν είναι εύκολη. Η ζωή στο χωριό είναι δύσκολη.

4.) Εγώ φοβάμαι να μπω στη σπηλιά. Δεν έχω θάρρος να μπω στη σπηλιά. Ο Δημήτρης είχε θάρρος.

Είχε πολύ φως και έκλεισε τα μάτια του. Οι πατούσες του ζεστάθηκαν. Έκανε πολύ ζέστη. Λίγο πιο πέρα είδε ένα σπίτι φτιαγμένο από έχυρα. Πηγαίνει κοντά και χτυπάει την ξύλινη πόρτα. Μία κοπέλα με μαλλιά άνοιξε την πόρτα.

- Ποιος είσαι;
- Είμαι ο Δημήτρης. Εσύ ποια είσαι;
- Εγώ είμαι η Ζέστη. Τι θέλεις;
- Ψάχνω να βρω το Δροσερό Νερό.
- Το Δροσερό Νερό είναι μέσα στη σπηλιά.
- Το Δροσερό Νερό γίνεται κρύο μέχρι να φτάσω στο χωριό μου.
- Το Ξέρω. Πρέπει να σκεφτείς μόνος σου με ποιον τρόπο θα μετεφέρεις το δροσερό νερό.

«Ίδιο μπαίνει ίδιο βγαίνει
Ίδιο η ζέστη και το κρύο
Άλλα μάτια πρέπει να'χεις
Και μυαλό να κατάλαβες.»

Ο Δημήτρης δεν κατάλαβε τίποτα.

- Βοήθησε με λίγο ακόμα, είπε.
- Εσύ πρέπει να σκεφτείς μόνος σου! Απάντησε θυμωμένη η Ζέστη.

Ο Δημήτρης γύρισε την πλάτη του να φυγει. Ξαφνικά! Οι πατούσες του άρχισαν να καίνε. Το χώμα έγινε πολύ ζεστό. Ο Δημήτρης δεν είχε παπούτσια. Ξαφνικά! Είχε μια ιδέα!! Το μυαλό του πήρε στροφές!!!

Βγάζει το μαχαίρι και κόβει τη μάλλινη τσάντα του στη μέση. Κόβει δύο κομμάτια σχοινί, τυλίγει τις πατούσες του με τα μάλλινα κομμάτια και (τα) δένει με το σχοινί. Κατάφερε και βγήκε έξω από το σπίτι. Οι πατούσες του σταμάτησαν να καίγονται!! Απέναντι βλέπει τη γκρι πόρτα. Η γκρι πόρτα είχε ένα φεγγάρι. Έβγαλε τα μάλλινα κομμάτια από τα πόδια του, τα κρέμασε στο λαιμό του, άνοιξε την πόρτα και μπήκε μέσα....

Ερωτήσεις

1. Όταν ο Δημήτρης φόρεσε τα μάλλινα παπούτσια συνέχισε να καίγεται;
2. Γιατί η Ζέστη θύμωσε;
3. Όταν έχουμε ένα πρόβλημα πρέπει να ζητάμε τη λύση έτοιμη ή να προσπαθούμε μόνοι μας;

1. Όταν ο Δημήτρης φόρεσε τα μάλλινα παπούτσια, σταμάτησε να παίζει.

2. Ο Δημήτρης ρωτάει συνέχεια με ποιον τρόπο να μεταφέρει το δροσερό νερό. Η ζέστη θύμωσε. Η συμπεριφορά του Δημήτρη ήταν λάθος. Αυτός έπρεπε να σκέφτει μόνος του την λύση.

3. Όταν έχουμε ένα πρόβλημα δεν πρέπει να ζητάμε τη λύση έτοιμη. Εμείς πρέπει να προσπαθούμε μόνοι μας. Εμείς πρέπει να σκεφτόμαστε τη λύση μόνοι μας.

Το δροσερό νερό

Το δωμάτιο ήταν γεμάτο χιόνι. Τα πόδια του Δημήτρη άρχισαν να καίγονται.

Γιατί καίγονται τα πόδια μου; Σκέφτηκε. Αυτό είναι πολύ παράξενο!

Ο Δημήτρης έσκυψε (σκύβω) και φόρεσε πάλι τα μάλλινα παπούτσια του. Όταν σηκώθηκε είδε ένα αγόρι με άσπρα μαλλιά.

-Ποιός είσαι εσύ; Ρώτησε το αγόρι.

-Εγώ είμαι ο Δημήτρης. Εσύ ποιός είσαι;

- Εγώ είμαι το Κρύο. Τι θέλει;

- Ψάχνω να βρω το δροσερό νερό.

- Το δροσερό νερό είναι μέσα στη σπηλιά.

- Το νερό της σπηλιάς γίνεται ζεστό μέχρι να φτάσω στο χωριό μου.

- Πρέπει να βρεις μόνος σου τη λύση.

- Με ποιον τρόπο.....;

- *«Ίδιο μπαίνει ίδιο βγαίνει*

Ίδιο η ζέστη και το κρύο

Άλλο μυαλό πρέπει να' χεις

Και μυαλό να καταλάβεις.»

Αυτό το ποίημα (μου) το είπε η Ζέστη. Η γειτόνισσά σου.
Δεν είναι γειτόνισσα μου. Είναι η αδερφή μου.
Συμφωνήσατε να πείτε το ίδιο ποίημα; Θελετε να κοροϊδέψετε εμένα; Εγώ ξέρω (ότι) η Ζέστη και το Κρύο είναι εχθροί. Πες μου τη λύση.
Πρέπει να βρείς μόνος σου τη λύση. Απάντησε θυμωμένο το κρύο και έδιωξε το Δημήτρη.

Ερωτήσεις

1. Σου άρεσε το πείραμα;

Το πείραμα μου άρεσε πολύ. Αυτό ήταν παράξενο. Η κυρία εξήγησε με ποιον τρόπο το κρύο χέρι έγινε ζεστό και το ζεστό χέρι έγινε κρύο.

Το δροσερό νερό (συνέχεια)

Ο Δημήτρης γύρισε την πλάτη και βγήκε από το κρύο δωμάτιο. Περπάτησε θυμωμένος και κάθισε στο βράχο. Έβγαλε τα μάλλινα παπούτσια του και άρχισε να τρώει ψωμί και ελιές. Ξαφνικά, βλέπει δίπλα στα πόδια του ένα παράξενο ζώο. Μια άσπρη σαύρα. Ο Δημήτρης έριξε λίγο ψωμί στη σαύρα και η σαύρα είπε:

- *«Ίδιο μπαίνει ίδιο βγαίνει*
  Ίδιο η ζέστη και το κρύο
  Άλλα μάτια πρέπει να' χεις
  Και μυαλό να καταλάβεις.»

Ο Δημήτρης έμεινε **έκπληκτ**ος!

- Με τάϊσες και δεν ζήτησες τίποτα άλλο. Ήταν σειρά μου να σε βοηθήσω. *Είπε η σαύρα.*

Η σαύρα έδωσε την ίδια συμβουλή με τη Ζέστη και Το Κρύο.

Ο Δημήτρης είναι πολυ μπερδεμενος. Προσπαθεί να καταλάβει. Ξαφνικά! Το μυαλό του πήρε στροφές.

Ο Δημήτρης φόρεσε πάλι τα μάλλινα παπούτσια και πήγε στη Ζέστη.

- Κυρία Ζέστη! Φώναξε. Θέλω καινούρια μάτια με αποτέλεσμα να καταλάβω καλύτερα.

Η Ζέστη χαμογέλασε και έδωσε στο Δημήτρη μισό ζευγάρι κόκκινα γυαλιά. Ο Δημήτρης δεν έκανε καθόλου παράπονα και ευχαρίστησε τη Ζέστη.

Μετά πήγε στο Κρύο και ζήτησε άλλα μάτια! Το κρύο έδωσε στο Δημήτρη μισό ζευγάρι μπλε γυαλιά. Ο Δημήτρης ευχαρίστησε το Κρύο και βγήκε απο τη σπηλιά. Κάθισε στον ήλιο να στεγνώσει και έβγαλε από την τσέπη του τα δύο κομμάτια γυαλία..!

<u>Ερωτήσεις</u>

1. Γιατί η σαύρα βοήθησε το Δημήτρη;
2. Εσύ όταν βοηθάς ένα φίλο σου μετά ζητάς να πάρεις ένα δώρο (ζητάς χάρη) ;

1. Η σαύρα βοήθησε το Δημήτρη γιατί ο Δημήτρης δεν ζήτησε τίποτα. Ο Δημήτρης δεν ζήτησε χάρη.

2. Όχι, εγώ όταν βοηθάω ένα φίλο μου, δεν ζητάω χάρη.

Το δροσερό νερό

Ο Δημήτρης ένωσε τα δύο κομμάτια και (τα) φόρεσε. Δεν είδε τίποτα. Όλα ήταν θολά. Χώρισε πάλι τα γυαλιά και φόρεσε μόνο το μπλε κομμάτι.

Βλέπει μέσα στο δροσερό νέρο πολλά μπλε αγόρια (που) μοιάζουν με το κρύο! Μερικά είναι βαθιά μέσα στην πηγή. Μερικά ακουμπούν πάνω στο νερό. Τα αγόρια (που) ακουμπούν πάνω στο νερό δεν μπορούν να μείνουν μέσα στην πηγή. Με αποτέλεσμα να βγαίνουν από το νερό και να φεύγουν μακριά.

Μετά φόρεσε το κόκκινο κομμάτι. Μέσα στο νερό είδε λίγα ξανθά κορίτσια (που) έμοιαζαν με τη Ζέστη. Μετά κοίταξε τον αέρα! Ο αέρας ήταν γεμάτος ξανθά κορίτσια! Τα ξανθά κορίτσια έκαναν βουτία στην πηγή και προσπαθούσαν να μείνουν μέσα.

Ο Δημήτρη σκέφτηκε: Πρέπει να εμποδίσω τα ξανθά κορίτσια να μπαίνουν στο δροσερό νερό. Ακόμα πρέπει να εμποδίσω τα μπλε αγόρια να βγαίνουν από το νερό.

Πήρε το ασκί, έβαλε μέσα το δροσερό νερό και φόρεσε το μπλε κομμάτι γυαλιού. Είδε πολλά αγόρια να βγαίνουν. Μετά φόρεσε το κόκκινο κομμάτι. Είδε πολλά κορίτσια να μπαίνουν.

Θυμήθηκε τα μάλλινα κομμάτια!! Τύλιξε το ασκί με τα μάλλινα κομμάτια. Φόρεσε πάλι το μπλε κομμάτι γυαλιά. Τα αγόρια δεν μπορούσαν να βγουν έξω. Μετά φόρεσε πάλι τα κόκκινα γυαλιά. Τα κορίτσια δεν μπορούσαν να μπουν μέσα!!

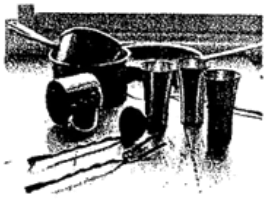
Ο Δημήτρης βρήκε τη λύση!!

Έτρεξε γρήγορα και πήγε στο χωριο του! Πρόσφερε το δροσερό νερό στη μητέρα του και στη γειτονια!! Όλοι ήταν έκπληκτοι! Το νερό ήταν δροσερό!! Αυτό δεν έχει γίνει ζεστό! Πολλοί άνθρωποι του χωριού πήγαν στην πηγή και μετέφεραν το δροσερό νερό στο χωριό με τον ίδιο τρόπο. Ο Δημήτρης ήταν ένας ήρωας!

Θερμότητα

Η θερμότητα μεταφέρεται από το ζεστό σώμα στο κρύο σώμα, μέχρι θερμοκρασία να γίνει ίδια.

Καλός αγωγός της θερμότητας: Οι καλοί αγωγοί **επιτρέπουν** τη διάδοση τη θερμότητας.



- χαλκός

- αλουμίνιο

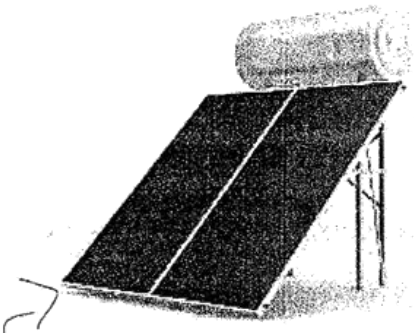
- σίδερο

Κακός αγωγός της θερμότητας: Οι κακοί αγωγοί <u>δεν επιτρέπουν</u> τη διάδοση τη θερμότητας.

- ξύλο
- αέρας
- χαρτί
- πέτρες
- μάλλινο ύφασμα
- πλαστικό
- φελιζόλ

Θερμότητα

Τα αντικείμενα με **σκούρα** χρώματα *(απο)ρροφούν* το φως, με αποτέλεσμα να ζεσταίνονται περισσότερο.



Ο ηλιακός θερμοσίφωνας έχει σκούρο χρώμα. Αυτός απορροφάει το φως του ήλιου με αποτέλεσμα να έχουμε ζεστό νερό.

Τα αντικείμενα με ανοιχτά χρώματα δεν απορροφούν το φως. Τα ανοιχτά χρώματα σκορπίζουν το φως.

Οι άνθρωποι (που) ζουν σε χώρες με πολύ ήλιο, επιλεγουν να φορούν άσπρα ρούχα με αποτέλεσμα να ζεσταίνονται λιγότερο.

Την Παρασκευή φτιάξαμε μια κατασκεύη. Στόχος της κατασκευής είναι να μεταφέρουμε παγωτά το καλοκαίρι *χωρίς να λιώσουν*.

1ο βήμα

Κόψαμε δύο κομμάτια χαρτί και δύο κομμάτια "ξύλο"(φελλό). Βάλαμε τα τέσσερα κομμάτια στις πλευρές του τελάρου. Το χαρτί και το ξύλο θα εμποδίσουν τη θερμότητα να μπεί στο τελάρο.

2ο βήμα

Μετά τυλίξαμε το τελάρο με πλαστικό. Δέσαμε το πλαστικό με σχοινί γύρω-γύρω από το τελάρο.Το πλαστικό είχε μικρές φυσαλίδες. Οι φυσαλίδες έχουν μέσα τους αέρα. Ο αέρας και το πλαστικό εμποδίζουν τη θερμότητα να μπει στο τελάρο.

3οβήμα

Τυλίξαμε με πλαστικό το πάνω μέρος του τελάρου.

4ο βήμα

Βάλαμε ένα άσπρο χαρτί στο πάνω μέρος του τελάρου. Τα ανοιχτά χρώματα δεν απορροφούν το φως. Τα ανοιχτά χρώματα σκορπίζουν το φως.

4ο βήμα

Αφήσαμε ανοιχτό το μπροστινό μέρος του κουτιού μέχρι τη μέση.

School C:

Φύλλο Κατασκευής

Όνομα Ομάδ[redacted]

1. Ποιες αλλαγές θα κάνω και γιατί;

Χρισιμοπιισα αρτα τα ηλη και σιακ φτιαξω ενα χαρτινο ψηγιο

κου

μετάφραση

Χρησιμοποίησα αυτά τα υλικά για να φτιάξω ένα χάρτινο ψυγείο

2. Τι άλλα υλικά θα χρησιμοποιήσω για την κατασκευή μου;

Χαρτινοκουτι κοματια χαρτιων βαμβακκολαταινια

1) Χάρτινο κουτί
2) βαμβάκι
3) κομμάτια χαρτιών
4) κόλλα
5) ταινία

Φύλλο Παρατήρησης

Το φύλλο παρατήρησης είναι για να σε βοηθήσει με τα πειράματα που θα γίνουν μέσα στην τάξη και είναι ένα καλό εργαλείο για να θυμάσαι όλα αυτά που έχει δει τα οποία θα σε βοηθήσουν στην κατασκευή σου!

Πειράματα

Από το πείραμα με τις λεκάνες: Πόσο καλά καταλαβαίνω με τα χέρια μου τι είναι ζεστό και τι κρύο; Γιατί να μην συμφωνούν τα χέρια μου και να αισθάνομαι διαφορετικά κάθε φορά;

(λόγια του [redacted]

λεκάνη με κρύο νερό → κρύωσε το χέρι!
λεκάνη με ζεστό νερό → ζεστάθηκε άλλο

διαφορά θερμοκρασίας νερού αισθανόμαστε στο χέρι.

Το πείραμα με το μπαλόνι

Υπόθεση που κάνω ΠΡΙΝ το πείραμα (Τι θα πάθει το μπαλόνι;): λόγο [redacted]

1) Τι μπουκάλι χρησιμοποιώ; Πλαστικό ή γυάλινο

2) Τι υλικό θα χρησιμοποιήσω;

3) Τη σόδα τη ρίχνω στο μπαλόνι και το ξύδι στο ζεστό γυάλινο μπουκάλι. Το μπαλόνι το βάζω στο στόμιο του μπουκαλιού.

Τι θα πάθει το μπαλόνι; Θα φουσκώσει ή όχι; Γιατί θα φουσκώσει;

Τι παρατηρήσαμε; Τι έπαθε το μπαλόνι; Μπορείς να εξηγήσεις τι έγινε με τα «κοριτσάκια»;

(Λόγια [redacted])

Με τη σόδα φαγητού στο μπαλόνι και το ξύδι στο γυάλινο μπουκάλι (γεμίσαμε [illegible] με βραστό νερό) και η θερμότητα μεταφέρθηκε στο μπαλόνι, γι' αυτό και φούσκωσε.

Φύλλο Κατασκευής

Όνομα Ομάδα [redacted]

1. Ποιες

Ξυλινη ψυχρα γιατί βοηθάει να είναι το νερό κρύο.

2. Τι άλλα υλικά θα χρησιμοποιήσω για την κατασκευή μου;

Θα χρησιμοποιήσω ξυλινη κόσα, αλουμινο χαρτο, υφασμα, ταινια, μολυβι, κολλα, ψαλιδι, χαρτονι, φελλο.

Φύλλο Κατασκευής

Όνομα Ομάδα[redacted]

1. Ποιες [redacted]

Απο χαρτί κουτί γιατι πιστευω οτι θα
είναι καλο φωγειο.

2. Τι άλλα υλικά θα χρησιμοποιήσω για την κατασκευή μου;

Θα χρησιμοποιήσω τα υλικά ..

Χο ντρο χαρτονι αφρολεξ καρφσον μπ
λε, κολλα, ψαλιδι, ταινια ℓ9

Translations from the worksheets from school B and C:

The cool water

Once upon a time....he was very sad.

Questions

1. What kind of grimace do you believe that Dimitris's mother did? (I show the grimace)
2. Was the behavior of Dimitris's mother, right?
3. How did Dimitris feel?

Answers

The behavior of Dimitris's mother was not right. She did a grimace and she said: "The water is not cool anymore. It became warm. It tastes like the village's water. The mother should have said: "It doesn't matter. Next time, I am sure you are going to make it".

> 3. Dimitris felt sad. He was sad.

Dimitris felt sad but,…pushes the yellow door and walks inside.

Questions

1. Does Dimitris live in a village or a city?
2. Did Dimitris's story happen three years ago or more years ago?
3. Is the life in the village easy?
4. Do you have the courage to enter the cave?
5. You decide to give advice to Dimitris. With what sort of way do you think will he be able to transfer the cool water in order not to become warm?

Ideas

With a plastic bottle. I wrap up the bottle with something made of paper.

Answers

>1. Dimitris lives in a village.

>2. Dimitris had been living there many years ago. Dimitris does not live there anymore. He used to live there many years ago, because: a) He did not have a car to go to the water source and b) He did not have a refrigerator to put the water inside.

>3. Life in the village is not easy. It is quite difficult.

>4. I am afraid to go inside the cave. I do not have the courage to do it. Dimitris instead had the courage to do it.

It had so much light…he opened the door and walked inside.

Questions

1. When Dimitris wore the woolen shoes, did he continue to sunburn?
2. Why did Heat get upset?
3. When we face a problem, should we ask for a ready solution or should we try to find a solution by ourselves?

Answers

>1. When Dimitris wore his woolen shoes, he stopped to sunburn.

>2. Dimitris is asking all the time with what way he can transfer the cool water. Heat got upset. Dimitris's behavior was wrong. He should have thought the solution by himself.

>3. When we face a problem, we do not have to seek a ready solution. We should try and think about finding the solution by ourselves.

The room was full with snow…the cold got upset and kicked Dimitris out of the room

Questions

1. Did you like the experiment?

Answers

I liked the experiment a lot. It was strange. Our teacher explained with what way the cold hand became warm and vice versa.

Dimitris turned his back….he pulled out of his pocket the two shards of glass

Questions

1. Why did the lizard help Dimitris?
2. When you help a friend of yours, do you ask him/her to buy you a present (or ask for another kind of favor) after having helped him/her?

Answers

>1. The lizard helped Dimitris, because he did not ask for anything. He did not ask for a favor.

>2. No, when I help a friend of mine, I do not ask for a favor.

Dimitris combined the two shards together…Dimitris was a hero

HEAT

Heat is transferred from the warm object to the cold one, until the temperature is the same for both objects.

Good heat conductor: Good heat conductors allow the distribution of heat. Copper, aluminum, iron are materials that are good heat conductors.

Bad heat conductor: Bad heat conductors do not allow the distribution of heat. Wood, air, paper, stones or rocks, woolen fabric, plastic and styrofoam are materials that are bad heat conductors.

Objects with dark colors absorb light, and with that way they are becoming warmer.

The water heater has a dark color. It absorbs sunlight and with that way we can use warm water.

Objects with light colors do not absorb light. Light colors scatter light.

People, who live in countries with large amounts of sunlight, choose to wear white clothes in order to feel less warm.

On Friday, we made a construction. Aim of the construction was to transfer ice creams during the summer without being melted.

Step 1

We cut two pieces of paper and two pieces of wood (cork). We put the four pieces around the box sides. Paper and wood will hinder heat to enter the box.

Step 2

Then we wrapped up the box with plastic. We tied up the whole box and the plastic with rope. Plastic had some small bubbles. There is air within the bubbles. Air and plastic hinder heat to enter the box.

Step 3

We wrapped up with plastic the upper side of the box.

Step 4

We put a white piece of paper on the upper side of the box. Light colors do not absorb light. Light colors scatter the light.

Step 5

We left open the upper side of the box until the middle.

Construction sheet

Team name: A

1. What changes will I make and why?

I used these materials in order to construct a paper refrigerator.

2. What extra materials will I use for my construction?

A paper box, cotton, pieces of paper, glue and tape

Observation's sheet

Experiments

According to the experiment with the basins, how well do I understand with my hands what is warm and what is cold? Why do I feel my hands different every time?

The basin with cold water cooled my hand, while the basin with warm water warmed my hand. The difference in the water heat is observed on the hand.

Experiment with the balloon

An assumption I make before the experiment (What is going to happen to the balloon?)

1. What kind of bottle do I use? A plastic or a glass one?
2. What materials will I use?
3. I put the soda inside the balloon and the vinegar inside the warm glass bottle. I put the balloon on the bottle's spout. What will happen to the balloon? Will it be inflated? Why will it be inflated?

What did we observe? What happened to the balloon? Can you explain what happened with the "little girls"?

With the baking soda inside the balloon and the vinegar inside the warm glass bottle (it warmed up earlier with boiling water), heat was transferred to the balloon, which was inflated.

Construction sheet

Team Name: Z and M

1. Which changes should I apply and why?

We should construct a wooden refrigerator, because it will help to keep the water cold.

2. What other materials will I use for my construction?

We will use a wooden box, aluminum foil, fabric, adhesive tape, scissors, glue, sellotape and cork paper.

Construction sheet

Team Name: C and T

1. Which changes should I apply and why?

We should construct a paper refrigerator because we believe it would be an effective construction

2. What other materials will I use for my construction?

We will use thick carton, glue, scissors, adhesive tape, plastic sheet with bubbles

Appendix 9: The informed consent

Signed consent of parents for the conduct of a research

Dear parents,

My name is Konstantina Kemou and I am a postgraduate pupil at the University of Gothenburg in Sweden. As part of my diplomatic research, a research project regarding the subject of natural sciences will be conducted at your children's school with the help of the school's teachers. The following text provides information about the research and the data collection. You can sign at the bottom of the page, if you agree to give me permission to gather data from the project that will be conducted inside the classroom.

1. RESEARCH OBJECTIVES: The purpose of the research is to detect whether the use of a story during the teaching of the natural sciences' subject regarding the chapters of heat and conductivity leads to better comprehension of these concepts with regards to the children who attend in deaf schools.
2. RESEARCH PROCEDURE: The data collection will be conducted using questionnaires before and after the teaching sessions, which will be carried out by the class teacher to identify if there any changes in how pupils think about the concepts of heat and conductivity. Furthermore, material during teaching sessions (worksheets to be filled by pupils, their drawings, etc.) will be used to assess their progress during the teaching sessions. The expected time for the completion of the questionnaires is at most 30 minutes.
3. EXPECTED BENEFITS FROM THE RESEARCH: The benefits of the research are expected to be multiple. First, pupils will have contact with concepts of natural sciences in an innovative and pioneering way that will lead to their better learning and understanding of the physical concepts. Secondly, the results of the research will lead to the reinforcement and enhancement of the natural sciences' teaching practices for deaf or hard of hearing pupils. Finally, the whole research will contribute to the academic literature strengthen regarding teaching practices of natural sciences.
4. POTENTIAL RISKS/DIFFICULTIES: Pupils may find difficulties in understanding and completing the questionnaires.
5. ANONYMITY/PROTECTION OF PERSONAL DATA: Pupils will not need to write their names or provide any other personal information in the questionnaires to be answered. The questions will clearly concern their ideas about natural phenomena.
6. REFUSAL/DISCLAIMER: Pupils have the right not to complete the questionnaires before and after the project. Moreover, you have the right to request from the researcher for your children's questionnaires not to be used during the data analysis.

Yours sincerely,

Konstantina Kemou

3/1/2016

7. CONSENT/SIGNATURE:

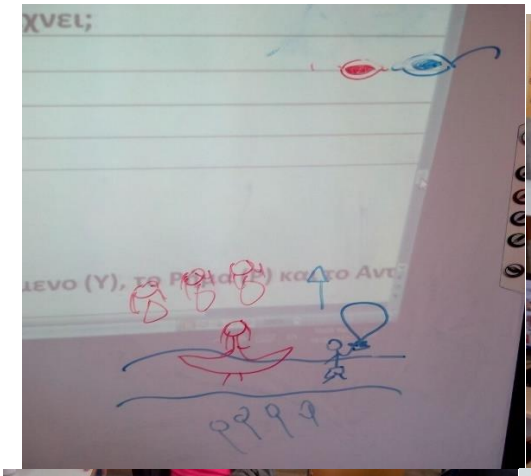
I responsibly state that I accept my child's participation in the survey. My child holds the right to withdraw from the research process at any stage of its conduct.

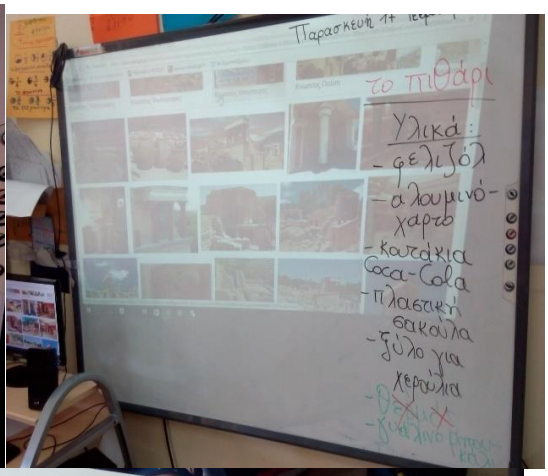
SIGN OF PARENT OR LEGAL GUARDIAN/DATE:

Appendix 10: Pictures

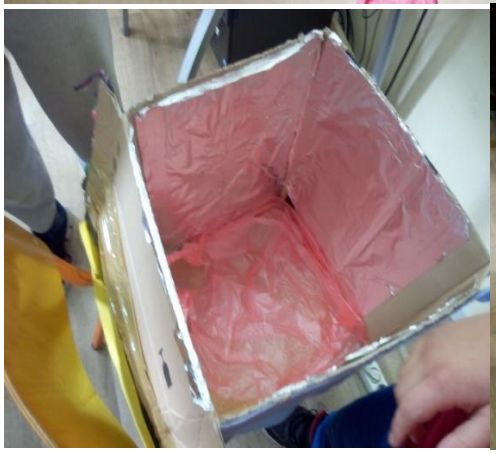
Pictures from the experiments and final construction of the kids.

School A:





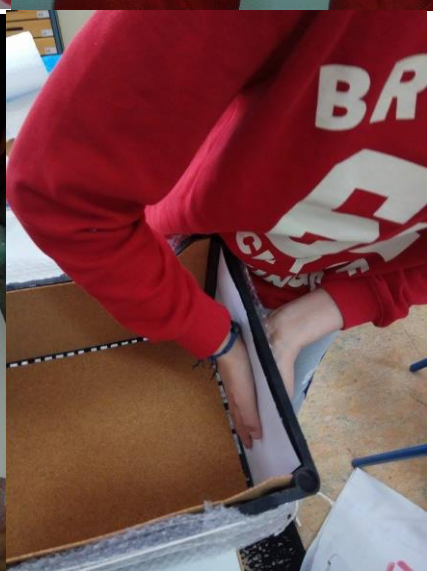





School B:




BROOKLYN

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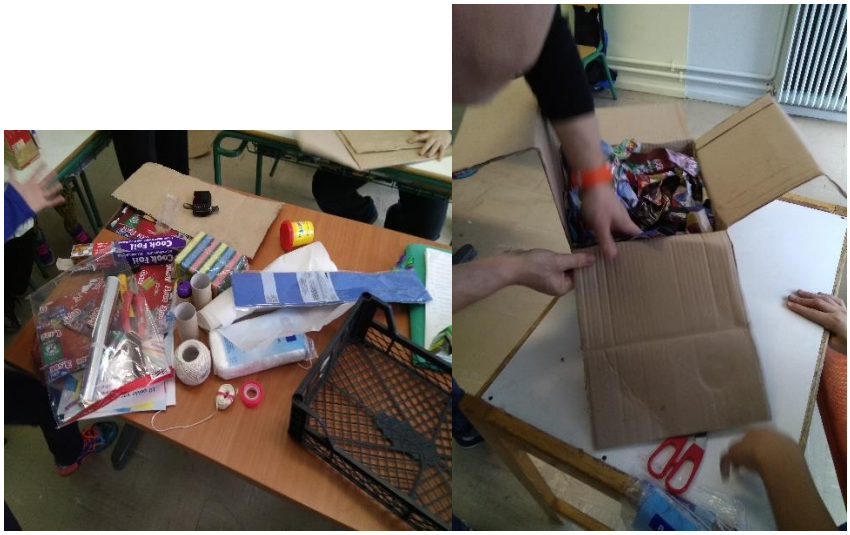

Appendix 11: The letter to the schools

Translated from Greek:

Good evening,

My name is Konstantina Kemou, a graduate of the Department of Primary Education of the University of Thessaly, and now a postgraduate pupil of the University of Gothenburg, Sweden. I communicate with you wishing to build with you an initial communication channel on the basis of which I seek to explore the possibility of a joint research cooperation.

In particular, during this period, I am in the process of initiating the writing of a research proposal in the context of my thesis project. This proposal concerns the exploration of the learning effects of teaching tools of interdisciplinary teaching of the subjects of Science and narrative speech (Literature) to deaf pupils.

This preliminary research idea attempts to be based on the jointly- with teacher and pupils- building of a project which will then be applied in one of the sections of the school during the school year 2016-2017. Teachers' participation in this process of co-building is a key principle of exploiting their accumulated knowledge and experience and ensuring the joint co-ownership of this educational action.

It is worth noting that the whole research will not burden the teachers and the school unit in general, in any way, except for the interest and the good mood of the participants! It goes without saying that the researcher will bear the cost and the responsibility of developing the necessary teaching materials, tools and action plans that will be co-decided with the teachers that will participate on the project. At the same time, it is worth noting that the targeted thematic units that will be developed will be in line with the school curriculum and the aims of the class's educational staff. Finally, it is noted that this research is supervised by two supervisors of the Departments of Education and Special Education at the University of Gothenburg.

Having shared the basic idea of my project above, I hope in a more direct communication and in our engagement in a more extensive dialogue on this subject- always according to and respecting your already burdened agenda. You can contact me on the details that appear below. I remain at your disposal by thanking you in advance for you time and interest.

Yours sincerely,

Konstantina Kemou

International Master Programme of Educational Research

Faculty of Education

Department of Education and Special Education

Gothenburg University

Appendix 12: Thematic analysis table

Examples from the interview	Keywords	Categories	Themes
-"I was extremely interested in the project." -"The whole project was worth of implementing"	Whole, Project, opportunity, interested, that part, in general, the process, methodology, complete	Teacher's general impression about the project.	Teacher's perspective
-"Deaf children need a more experiential way" -" Deafness can affect negatively the development of imagination"	Deaf, Culture, leaning, deaf behavior, deafness, hearing/hard of hearing kids, Deaf education, Deaf learning	Comments about deaf education/ how deaf people learn	
-" I would like to change the story" -" There was the idea…"	Change, new, idea, alternative way	Changes/new ideas that they propose about the planning	
-"The kids reacted to the problem by having the urge to see how we would do it." -" I saw them having a lot of interest" -"The kids were very curious about the story"	Interest, like, love, nervous, confidence, urge, lust, excited, impressed, bored, nervous, stressed, smile, stand up, wide eyes, react, important, goal, control	Teacher's opinion about pupil's motivation	Motivational issues
-" I had a small worry that it could take a lot in time…" -" The only negative that I feel is that the theoretical part didn't work as I expected"	Worries, problematized, challenge, negative, lack of time, afraid, not sure, it was difficult	Teacher's worries, challenges and negatives.	Positives and negatives of the project
-" I liked that the story was easily understandable. -" I thought this procedure would help the pupils…"	Liked, preferred, it was helpful, I enjoyed, I found positive, the benefits are many, effectively, it was important, worth, better	Positives of the project (story, experiments, final product)	
-" We interpret the story in sign language" -" I introduced the project to the pupils by…" -" We used a lot the projector…"	Worked, taught, did, interpreted, changed, plans, teach in different ways, introduced, split, time, watch, discuss, experimented, constructed, used	Teaching practices inside the class from the project. Application of the planning	Teaching practices

-“ Me and the other teacher did not intervene in children’s thinking”	behaved, influenced, supported, engage, navigate, intervene	The role of the educator	
-“ I usually prepare for them an "advance organizer	Usually, teach, way, I prepare, I give them, books, no physics, exercises	Alternative teaching practices in the past	
-“ Almost all of the kids understood the image” -“The pupils justified the reason of choosing the woolen fabric because…”	Understanding, learning, expressing gestures, examples, participation, comparisons, critical thinking, suggestions, scientific explanations,	Teacher’s opinion about pupil learning and understanding/ examples of their understanding Behavior that indicates learning	Pupils’ learning according to the teacher
-“I think that first of all there is limited school infrastructure” -“ I will give you some examples to explain why kids find some linguistic difficulties.” -““There was different discriminations in the class.”	School, settings, atmosphere, collaboration, classroom, facilities, extra difficulties, diagnosis	Environment/ school settings Pupil collaboration School Facilities/ Technologies	Environmental context