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THE USE OF TEXT IN FACILITATING SIXTH GRADE STUDENTS' PERSONAL EPISTEMOLOGY ADVANCEMENT IN SCIENCE

DOCTORAL DISSERTATION

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Abstract

Two text-based instructional interventions that emerged from two antithetical theoretical frameworks were developed and contrasted in terms of their effectiveness in facilitating sixth grade students' personal epistemology in science. The *refutation text intervention* emerged from the epistemological theories framework (Hofer & Pintrich, 1997) and the *analogy text intervention* emerged from the epistemological resources framework (Hammer & Elby, 2002). The role of text comprehension, interest and prior knowledge in the process of epistemological advancement was investigated. The study also examined the structure of personal epistemology of 11-12 year old students in science. Sixth grade students (N=175) were randomly assigned in three text groups. Students in the baseline group (control group) read an expository text about epistemology in science. Students in the refutation group read a refutation text about epistemology in science and students in the analogy group read an expository text enriched with everyday analogies about epistemology in science. Students' personal epistemology was assessed with the Personal Epistemology in Science Questionnaire. Results indicated that all three texts induced change (however modest) in students' personal epistemology, while both the analogy text and, to a lesser extent, the refutation text enhanced substantially the epistemology of students with high comprehension ability. Partial support was provided for a four-dimensional structure of personal epistemology. Findings contribute to the understanding of the underlying structure of younger students' personal epistemology in science and support the feasibility of short-term instructional interventions towards personal epistemology advancement.

Περίληψη

Έγινε σύγκριση δύο διδακτικών παρεμβάσεων βασισμένων σε κείμενο οι οποίες αναπτύχθηκαν με βάση δύο αντίθετες θεωρητικές προσεγγίσεις, ως προς την αποτελεσματικότητά τους στην ανάπτυξη της προσωπικής επιστημολογίας μαθητών έκτης δημοτικού στην επιστήμη. Η *χρήση κειμένου αντιπαράθεσης* προήλθε από τη θεωρητική προσέγγιση των *επιστημολογικών θεωριών* (Hofer & Pintrich, 1997) και η *χρήση κειμένου με τη χρήση αναλογιών* προήλθε από τη θεωρητική προσέγγιση των *επιστημολογικών εφοδίων* (Hammer & Elby, 2002). Εξετάστηκε επίσης ο ρόλος της κατανόησης κειμένου, του ενδιαφέροντος και της προηγούμενης γνώσης στην επιστήμη στη διαδικασία ανάπτυξης της προσωπικής επιστημολογίας. Διερευνήθηκε επίσης η δομή της προσωπικής επιστημολογίας μαθητών ηλικίας 11-12 ετών στην επιστήμη. Μαθητές έκτης δημοτικού (N=175) κατανεμήθηκαν τυχαία σε τρεις ομάδες κειμένων. Οι μαθητές στην ομάδα ελέγχου διάβασαν ένα πληροφοριακό κείμενο για την επιστημολογία στην επιστήμη. Οι μαθητές στην ομάδα του κειμένου αντιπαράθεσης διάβασαν ένα κείμενο αντιπαράθεσης για την επιστημολογία στην επιστήμη και οι μαθητές στην ομάδα του κειμένου με τη χρήση αναλογιών διάβασαν ένα πληροφοριακό κείμενο εμπλουτισμένο με παραδείγματα από την καθημερινή ζωή σχετικά με την επιστημολογία στην επιστήμη. Η επιστημολογία των μαθητών εξετάστηκε με το Ερωτηματολόγιο Προσωπικής Επιστημολογίας στην Επιστήμη. Τα αποτελέσματα έδειξαν ότι και τα τρία κείμενα προώθησαν την αλλαγή (ωστόσο σε μικρό βαθμό) στην προσωπική επιστημολογία των μαθητών. Το κείμενο με τη χρήση αναλογιών και σε μικρότερο βαθμό το κείμενο αντιπαράθεσης προώθησε συστηματικά την επιστημολογία μαθητών με ψηλή αναγνωστική ικανότητα. Επίσης, τα αποτελέσματα υποστηρίζουν εν μέρει ότι η προσωπική επιστημολογία νεαρών μαθητών μπορεί να διακριθεί σε τέσσερις διαστάσεις. Τα αποτελέσματα της έρευνας συμβάλουν στην κατανόηση της δομής της προσωπικής επιστημολογίας μαθητών δημοτικού στην επιστήμη και υποδεικνύουν τη δυνατότητα παρεμβάσεων μικρής διάρκειας στην ανάπτυξη της προσωπικής επιστημολογίας.

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Introduction

Rationale

Beliefs about the nature of knowledge and knowing frame one's personal epistemology. Personal epistemology impacts numerous aspects of cognition such as text comprehension (Schommer, 1990), comprehension strategy use (Dahl, Bals, & Turi, 2005), interpretation of controversies, and topic-specific belief change (Mason & Boscolo, 2004). Moreover, personal epistemology impacts aspects of motivation such as goal setting processes (Braten & Stromso, 2004) and also conceptual change in science (Quian &Alvermann, 1995; Mason, Gava, & Boldrin, 2008). It also impacts argumentation, a basic skill in science learning (Naussbaum & Bendixen, 2003) and physics understanding (Stathopoulou & Vosniadou, 2007). Carey and Smith (1993) contend that in science, a more advanced epistemology enables students not only to master science content but also to value knowledge derived from careful experimentation and argumentation, and to develop a critical attitude toward the pronouncements of experts. In other words, students with advanced epistemology may evaluate scientists' claims on the grounds of their inquiry practices.

Within the context of the present study, advancement of personal epistemology is defined as the process of enabling students to view knowledge as a complex, dynamic and constantly evolving structure, derived from active construction and justified through dynamic inquiry processes. Despite the fact that this is a highly demanding process on students' part, early intervention is desirable. Researchers in the area (Schommer, 1990; Pajares, 1992; Elder, 2002; Schraw & Sinatra, 2004) underlined the importance of informing children in grade school (4-12 years old) about the integration and complexity of knowledge. Nevertheless, such instructional interventions are often complex and laborious. For instance, the study of Smith, Maclin, Houghton, and Hennessey (2000) indicated that in order to advance personal epistemology of elementary students in science, the same teacher needed to consistently train students for six years on knowledge building and understanding. Such effortful approaches though, may discourage teachers and schools from embracing them in order to facilitate epistemological advancement. There is therefore a need to develop less complex and more feasible interventions. To that end, the main goal of the current study was to design, develop and evaluate short-term instructional interventions aiming to facilitate sixth grade students' epistemological advancement in science.

Sound interventions derive from theories, and in turn theories inform measurement and evaluation efforts. In the domain of personal epistemology there are two main theoretical frameworks: the epistemological theories and the epistemological resources framework. The *epistemological theories* perspective assumes that personal epistemology is cohesive and theory-like, hypothetically comprised of four dimensions: certainty and simplicity pertaining to the nature of knowledge, source and justification pertaining to the nature of knowing (e.g. Hofer & Pintrich, 1997). The *epistemological resources* perspective on the other hand, assumes that personal epistemology is comprised of bits and pieces of epistemological resources, representing routines for thinking about everyday events (Hammer & Elby, 2003). Hammer and Elby (2003) suggest a number of possible epistemological resources that relate somewhat to the above dimensions but are much smaller cognitive structures.

The main difference between the two frameworks concerns the structure of personal epistemology. Researchers adopting the epistemological theories framework hypothesize that aspects of personal epistemology are organized in a cohesive and consistent structure expressed similarly across different contexts within the same subject (Hofer & Pintrich, 1997). Proponents of this framework are seemingly attributing a theory-like organizational structure to personal epistemology. On the other hand, researchers emphasizing the role of context, hypothesize that personal epistemology is a flexible structure, shaped according to the context, with different contexts activating different combinations of epistemological resources (e.g. Hammer, & Elby, 2003). Researchers who support the epistemological resources framework are thus assuming that personal epistemology is less of a cognitive and more of a social nature, due to the idiosyncrasies of its manifestations that are bound to context. The implications of each of the above theories in regard to designing instructional interventions are consequently divergent. A goal of the present study was to develop interventions based on these opposing assumptions about the structure of personal epistemology and compare their effectiveness in terms of advancing personal epistemology.

Evaluating the effectiveness of any intervention requires the use of valid and reliable measures of the construct that represents the intervention target. However, the great variety of measures that are currently being used by researchers in the area of personal epistemology suffer from theoretical shortcomings and reliability problems (DeBacker, Crowson, Beesly, Thoma, & Hestevolt, 2008). The originally hypothesized multidimensional structure of personal epistemology, as reflected by the inclusion of subscales for each dimension, has not been consistently supported by empirical testing. Individual subscales have been found to suffer, in general, from low internal consistency and, in some cases, subscales not strictly epistemological in nature (e.g. beliefs about ability) have also been part of instruments claiming a focus on personal epistemology. Moreover, DeBacker et al. (2008) observed that despite the widely accepted notion of domain specificity of personal epistemology, the majority of current instruments consist of general items applicable in a number of different domains. Such asymmetries though may hinder the process of measuring domain specific personal epistemology, failing thus to capture idiosyncratic epistemological aspects of each domain.

With respect to the content of the existing measures, Muis (2007) argued that there is also an ambiguity as to whose image of science students are required to reflect on as they complete such measures. In the same instruments there are items that refer to the work of scientists and other that ask students to report beliefs about their own endeavors in science. This echoed Hogan’s (2000) and Sandoval’s (2004) argument that a distinction should be made between formal and practical epistemology. Formal epistemology refers to students’ views about scientists’ work, while practical epistemology is related to students’ views about their own endeavors in doing science. In this research, a domain-specific instrument of personal epistemology in science was developed. It included 10 subscales designed to evaluate aspects of the nature of science, related to each of the four hypothesized dimensions (certainty, simplicity, source, and justification). The instrument focused on students’ formal epistemology, and language was appropriate for grade school students at the age of 11-12. Students’ formal epistemology was evaluated with two different formats of assessment: (a) with dichotomous (agree/disagree) statements that intended to measure personal epistemology directly (explicitly) and (b) with scenarios that intended to measure personal epistemology indirectly (implicitly). Results related to this instrument were expected to carry implications about the hypothesized multidimensional structure of personal epistemology and its manifestation in this, younger, age group.

It was considered that in designing an intervention in personal epistemology, beyond attention to measurement and theoretical issues, examination of a set of individual difference variables could provide insights about the process of personal epistemology advancement. This process was considered domain learning, as students pursued a fundamental topic in the domain of science: the nature of knowledge and knowing. According to the Model of Domain

Learning, interest, domain knowledge and recall and intertwined, and their interactive nature seems to impact domain learning (Alexander, Kulikowich, & Jetton, 1995). In that regard, this research examined two types of interest (personal and situational) and their potential influence on epistemological level and advancement. Moreover, two types of prior knowledge (domain and topic) and also text comprehension were also examined. These variables will all be delineated in a subsequent section.

In summary, the significance of this research was twofold: practical and theoretical. Firstly, the practical significance lied upon the development of feasible instructional interventions that schools and teachers would be eager to apply. Moreover, this study aimed to develop a domain specific personal epistemology instrument in science appropriate for grade school. However, beyond the practical aspect of instrument development, the study also examined the hypothesized multidimensional structure of personal epistemology and its manifestations in sixth grade school students. It was expected that a possible emergence of a dimensional structure would support a theory-like structure of personal epistemology, while the lack of clear emerging factors would carry implications of a fragmented structure. It was considered that this theoretical significance of the study would be further enhanced by the indirect comparison of the two opposing theoretical perspectives, via the contrast of the effectiveness of the two interventions, providing thus additional information about the structure of personal epistemology.

Personal Epistemology Advancement

The proposed research aimed to develop short-term text-based interventions to facilitate epistemological advancement of sixth-grade students in science. Two interventions that emerged from different theoretical perspectives were compared, the *epistemological theories* and the *epistemological resources* perspective. According to the epistemological theories framework, personal epistemology is a theory-like and consistent structure comprised of a number of more or less independent dimensions (e.g. Schommer-Aikins, 2004; Hofer, & Pintrich, 1997). On the other hand, according to the epistemological resources framework, personal epistemology is a fragmented and flexible structure, comprised of small cognitive elements, namely epistemological resources that correspond to early experience with learning and teaching situations at home, school and community settings (Hammer & Elby, 2002; 2003).

Personal epistemology consists of beliefs about the nature of knowledge and knowing and they are a part of one's complex belief structures. Belief structures consist of central and tangential beliefs (Pajares, 1992). For instance, beliefs related to one's identity can be considered central because they are more functionally connected to other beliefs, while beliefs about taste are considered tangential with fewer functional connections to other beliefs. Importantly, the more central a belief is, the more it will resist change (Pajares, 1992). Given the impact of personal epistemology on cognitive processes, one may infer that it is a central structure with many functional connections. Consequently, personal epistemology may be a structure resistant to change. This assumption is supported by outcomes of empirical studies that have shown that perhaps only parsimonious long term-efforts may result into advancing personal epistemology (e.g. Smith et al., 2000; Conley, Pintrich, Vekiri, & Harrison, 2004).

The issue of difficulty of change along with the assumptions of the epistemological theories perspective about the cohesiveness of personal epistemology, indicate possible similarities between the construct of personal epistemology and other conceptual structures. Therefore, the two processes of epistemological advancement and conceptual change may be considered analogous in certain respects. Posner, Strike, Hewson, & Gertzog (1982) reviewed research on conceptual change and concluded that there are certain necessary conditions for conceptual change to occur. One of those conditions considered to be influential in conceptual change research, is dissatisfaction with current conceptions. This feature parallels epistemic doubt, the respective necessary condition for belief change proposed by Bendixen (2002). The correspondence between these two essential conditions, lends further support of the similarities between the two processes.

As a result, common ground between conceptual change and belief change justifies the use of methods used in conceptual change research (Gill, Ashton, & Algina, 2004). An effective instructional medium in that research area is the use of refutation text that creates the necessary cognitive conflict for change to occur (Hynd, 2001; Guzzetti, Snyder, Glass, & Gamas, 1993). A refutation text acknowledges readers' alternative conceptions, refutes them and provides the scientifically accepted ones as more viable and superior (Hynd, 2001). Importantly, refutation text has been found to be particularly effective with elementary school students (Mason et al., 2008; Diakidoy, Kendeou, & Ioannides, 2003; Guzzetti et al., 1993).

Thus, the *epistemological theories intervention* featured the use of a <u>refutation text</u> about the four hypothesized dimensions of certainty, simplicity of knowledge and source and justification of knowing in science. The text challenged students' views about the four aspects of epistemology, by explaining why their beliefs were possibly not sufficient. It subsequently presented the advanced beliefs explicating their superiority.

While structure (refutational) was the guiding principle in designing the epistemological theories text, due to the assumed difficulty of change, the respective principle in developing the epistemological resources intervention text was the content. The content, featuring particular analogies familiar to students, was expected to create an effective context that would facilitate the activation and emergence of appropriate epistemological resources. This reasoning in designing the epistemological resources intervention stemmed from assumptions about a flexible structure consisting of small rudimentary epistemological elements (Rosenberg, Hammer, & Phelan, 2006) corresponding to everyday thinking routines. To facilitate advancement, those resources needed to be successfully activated (Hammer & Elby, 2002). That required alignment between students' available resources and the context of activation.

As a result, the effectiveness of this epistemological resources intervention lied upon identifying available epistemological resources in sixth grade students and in designing a context that would enable their activation singly, or in combination (some resources may be activated at the same time in order to induce advancement). Young children seem to be capable of epistemological thought at a basic level early on (Hammer, & Elby, 2002, Elder, 2002). For instance, they may reason about the source of knowledge, by replying "because I thought so" to the question "how do you know that?". Prior research provides evidence of advancement in epistemology, in contexts that were sensitive to students' available epistemological resources (Hammer & Elby, 2003; Louca, Elby, Hammer, & Kagey, 2004; Rosenberg, Hammer, & Phelan, 2006).

In that regard, sixth grade students' available epistemological resources corresponding to the four hypothesized dimensions of personal epistemology examined in this study, were identified in advance and were utilized to design an appropriate context. Consequently, the *epistemological resources intervention* featured an analogy text that presented in expository text format the same information as the refutation text about certainty, simplicity, source and justification of knowledge, supported nevertheless by the use of analogies. The analogies, representing potential epistemological resources, referred to everyday examples and corresponded to the aforementioned dimensions of epistemology.

Measuring personal epistemology

In order to evaluate the effectiveness of the interventions, the project also aimed to develop a focused instrument to measure certain aspects of epistemology in science appropriate for 11-12 year old students. The dimensions of epistemology were evaluated through the use of a two-part personal epistemology instrument that targeted students' beliefs about the nature of knowledge and knowing from the perspective of the scientists' work (formal epistemology). Given the caveats about measurement presented by DeBacker et al. (2008) this study used a domain-specific instrument consisting of items that referred to the nature of knowledge and knowing in science. The instrument measured formal epistemology avoiding items that referred to students' own efforts in science. Cypriot students in grade school were not expected to exhibit beliefs about their own efforts in science because the majority of the experiments they are required to conduct are dictated either by the book or the teacher. Two different forms of the instrument were developed and compared for their reliability, validity and appropriateness for this age group. Both parts of the instrument were developed based on the four dimensions. The first part consisted of dichotomous agree/disagree items, while the second part presented students with scenarios seeking to elicit their views in a less formal and indirect way. The hypothesized multidimensional structure of personal epistemology was examined using the results of both parts of the instrument.

Interest, Prior Knowledge and Text Comprehension

In order to gain a more complete understanding of the process of epistemological advancement, the project also examined the contribution of personal interest and prior knowledge in science in conjunction with text comprehension (Figure 1). It was expected that information about students' interest in science and their engagement in reading the texts could enhance our understanding of epistemological advancement. Personal interest concerns one's dispositions toward a domain, and it is a more or less stable characteristic of the person, while situation interest emerges from the interaction with a learning task and it is bound and strictly related to that (Ainley, Hidi, & Berndorff, 2002). Both personal interest in science and situation interest in reading the intervention texts were examined in this study.

Two measures of interest were used. Personal interest (Ainley, Hidi, & Berndorff, 2002) in science was measured with a questionnaire and situation interest (Ainley et al., 2002) was measured on-line four times throughout the reading of the texts. It consisted of a single question, appearing at the end of each section, requiring students to enter the degree to which they found the respective text section interesting.

In addition to interest, the study also examined the impact of prior knowledge. Prior knowledge impacts learning (Dochy, Segers, & Buel, 1999; Alexander, 2003) and may interact with interest to affect text comprehension (Alexander, Jetton, & Kulikowich, 1995). Given that the interventions were text-based and their comprehension was crucial in their effectiveness, prior domain knowledge was also examined. Domain knowledge represents the breadth of knowledge within a domain (e.g. science) and topic knowledge represents the depth of knowledge about a domain topic (e.g. electrical circuits) (Alexander, 2003).

In the context of this research however, topic knowledge could be considered analogous to personal epistemology. The main topic of the intervention texts was the nature of knowledge and knowing in science. Consequently, personal epistemology, as measured at the beginning of the intervention, provided an index of prior knowledge on this topic. Prior domain knowledge was measured with an instrument tapping knowledge in fifth-grade science content.

Students' text comprehension was considered critical, as it was expected to function as an intermediate variable towards the desired process of epistemology advancement (Figure 1). Consequently, assessment of text comprehension needed to result in a reliable and valid index of the information that students were expected to learn from the text. Text recall (memory for text), is often used as an index of text comprehension (Kendeou & van den Broek, 2005) and it is presented as a main factor in the model of domain learning (Alexander, Jetton, & Kulikowich, 1995). Nevertheless, text recall might fail to reveal possible conceptual change processes that may take place during reading (Kendeou, Muis, & Fulton, 2011; Kendou & van de Broek, 2007). This lack of effect in text recall however does not preclude learning from text (Kintsch, 1994). Therefore, in this research, both memory for text as well as learning from text were assessed with a main idea recall task and a free recall task, completed after reading. In addition, the comprehension ability of the students before the beginning of the study was also evaluated with a free recall task on a short expository text. Moreover, teachers of participating classes were asked to rate their students' text comprehension ability on a scale 1-5 and their ratings were considered as an additional index of students' text comprehension ability.

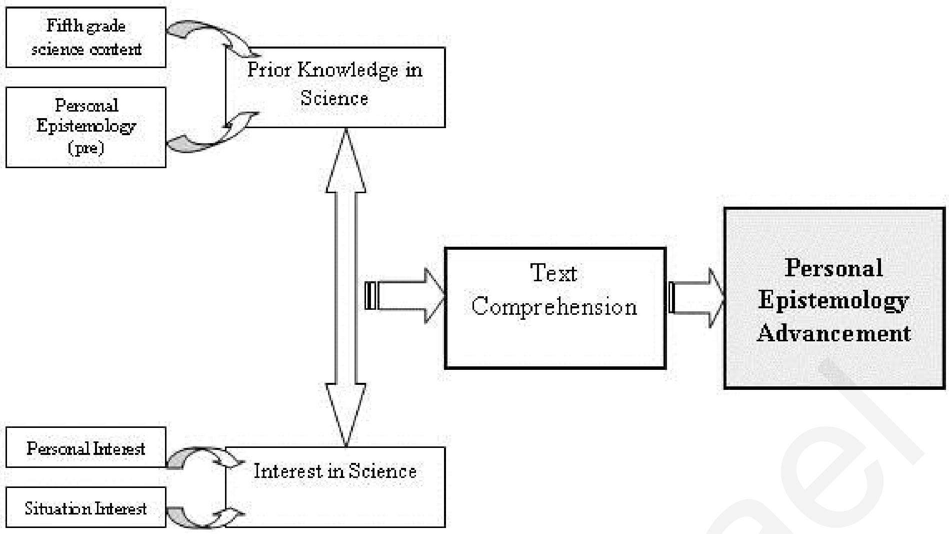

Figure 1. A text comprehension-based model of personal epistemology advancement

Research Questions and Hypotheses

This study aimed primarily to examine the effectiveness of short-term instructional interventions designed to promote personal epistemology advancement along with a set of secondary variables that were expected to impact the process of advancement. Three main research questions were asked:

1. Which text-based intervention was more effective in promoting epistemological advancement in science: the epistemological theories or the epistemological resources intervention? Moreover, what was the impact of text comprehension, interest and prior knowledge in the process of personal epistemology advancement? The two text-based instructional approaches were contrasted and compared in terms of their effectiveness in advancing sixth grade students’ personal epistemology. It was expected that the contrast of the two approaches would possibly generate insights about the structure of personal epistemology. It was reasoned that if the structure of personal epistemology of sixth grade students in science was coherent and theory-like, then, the refutation text about epistemology would create the necessary cognitive conflict and cause the greater epistemological advancement. On the other hand, it was expected that if the structure of personal epistemology of sixth grade students was incoherent, comprised of epistemological resources, then the analogy text about epistemology would help students activate productively their epistemological resources and lead to greater epistemological advancement.

In terms of the second part of the first research question about the role of text comprehension, interest and prior knowledge in personal epistemology advancement it was considered that according to the Model of Domain Learning (Alexander, Kulikowich, & Jetton, 1995), all three variables would have an impact. Text comprehension, in particular, was expected to have a direct effect on personal epistemology advancement because the effectiveness of the intervention lied in large measure upon comprehending the particular texts.

2. What was the role of interest and prior knowledge in text comprehension performance (comprehension of experimental texts)? Text comprehension was considered a pivotal variable in the process of personal epistemology advancement. Consequently the impact of interest and prior knowledge on text comprehension needed to be explicitly examined. On the basis of the Model of Domain Learning it was expected that interest and prior knowledge would interact and impact text comprehension. Moreover, it was reasoned that text type would also influence text comprehension via interactions with interest and prior knowledge.

3. To what extent a domain specific instrument in science measured the personal epistemology of 11-12 year old students reliably and validly and in addition, which form, dichotomous agree/disagree items or scenarios, seemed to be more appropriate for this younger age group? Moreover, how was the hypothesized multidimensional structure manifested in this younger age group? Items were diligently adapted from existing instruments and others were developed on the basis of three characteristics: (a) meet the needs of the target age group in terms of clarity in expression and language, (b) be domain specific and directly related to the four dimensions via the ten subscales, and (c) avoid items that involved students' own experiences in science. It was therefore expected that this instrument would reliably measure sixth grade students' personal epistemology. Furthermore, the two parts of the relevant questionnaire that corresponded to the explicit and implicit assessment of personal epistemology were expected to be comparable in terms of reliability and validity, because they were developed according to the same underlying structure (four domain specific dimensions, reflected in ten subscales). In respect to the multidimensional structure of personal epistemology, inconsistent outcomes of previous research did not enable the statement of coherent and sound predictions. Consequently, only nondirectional hypotheses could be articulated regarding this third research question: an emergent interrelated

dimensional structure was expected to support a theory-like view of personal epistemology, while on the other hand, the lack of emergent factors was expected to support the 'knowledge in pieces' view of personal epistemology.

Design

The study involved a main dependent variable, Personal Epistemology, which was examined at two levels, explicitly and implicitly. Text Type was the independent variable of the study. Three text groups were formed: (a) the Baseline group read an expository text about epistemology concerning the dimensions certainty, simplicity, source and justification of epistemology (control group), (b) the Refutation group read a refutation text about epistemology concerning the four dimensions of epistemology (epistemological theories intervention), and (c) the Analogy group read an analogy text about epistemology concerning the four dimensions of epistemology (epistemological resources intervention). There were therefore three levels in the independent variable: the baseline text, the refutation text and the analogy text. The contribution of interest in science (personal interest and situational interest), prior knowledge (domain knowledge and topic knowledge) and text comprehension (ability and performance) on personal epistemology advancement were also examined.

CHAPTER 2

Literature Review

The main goal of this study was to compare the effectiveness of two instructional interventions that derive from two contrasting, antithetical even, theoretical frameworks. Thus, the first part of this literature review aims to present these frameworks and highlight their differences in defining personal epistemology. Different definitions have implications in instructional practices and as a result guided the development of the two contrasted instructional interventions.

Defining Personal Epistemology

Two overarching theoretical perspectives can be identified in research on personal epistemology: a developmental perspective and a multidimensional perspective (Hofer & Pintrich, 1997). Frameworks that fall under the developmental perspective pursue research that is primarily concerned with sequential development (unitary structure that develops in stages) of personal epistemology, while frameworks under the multidimensional perspective correspond to research that regards personal epistemology a set of dimensions, related to or independent of each other.

There are five developmental frameworks that hypothesize that epistemological development takes place through a series of different qualitative levels of epistemological thought (Hofer & Pintrich, 1997; Muis, 2007). Despite the use of different terms to characterize each developmental level, there is an assumed developmental continuum, which is common among the different frameworks: absolutism/subjectivism, evaluatism/ objectivism, and evaluatism/objectivism-subjectivism. The first level implies a belief in objective, right/wrong, handed down by authority figures knowledge. At this stage there is a belief that knowledge represents a true state of the world. As students progress through different levels of education, at the third level of evaluatism they come to endorse the notion that knowledge should not be taken at face value and that it should be examined on the grounds of provided evidence. Importantly, in this latter stage people accept multiple perspectives.

Multidimensional frameworks on the other hand, consider personal epistemology to be organized into dimensions instead of stages, manifested in synchrony or independently (Muis, 2007). Within these frameworks, Hofer (2004) identified four underlying dimensions originally proposed by Hofer and Pintrich (1997) representing the tentativeness, complexity, sources and justification means of scientific knowledge. Several frameworks under the overarching multidimensional framework attribute to epistemology a theory-like structure (e.g. Hofer & Pintrich, 1997), while others (e.g. Hammer & Elby, 2002; 2003) presume that personal epistemology is an incoherent structure comprised of context-dependent epistemological resources. This study aimed to examine the differences between these two multidimensional perspectives and their potential influences in designing interventional studies to promote personal epistemology.

The focus of the current research on conceptual differences between frameworks necessitates attention to different definitions, as they carry theoretical implications (Hofer, 2008). Among both the developmental and the multidimensional overarching frameworks, there is an abundance of different terms denoting personal epistemology: ways of knowing (Belenky et al., 1998), epistemological reflection (Baxter Magolda, 2004), reflective judgment (King & Kitchener, 1994), argumentative reasoning (Kuhn, 1999), epistemological profiles (Muis, 2008), epistemological beliefs (e.g. Schommer, 1990), epistemic beliefs (Hofer, 2008), personal epistemology (Hofer, 2000), epistemological resources (Hammer & Elby, 2002).

The term ‘epistemological beliefs’ has been prominently used in studies conducted under the multidimensional paradigm. Recently, Hofer (2008) distinguished among the terms epistemological beliefs and epistemic beliefs. Hofer favored the term ‘epistemic’ arguing that the term ‘epistemological’ refers to beliefs about epistemology and not beliefs about knowledge and knowing. On the other hand, Hammer and Elby (2002) argued that the term ‘epistemological beliefs’ attributes to the construct trait-like qualities implying consistency among differential contexts and suggested instead the term ‘epistemological resources’. Hofer and Sinatra (2010) shared similar concerns about terms that entail dispositional characteristics to the conceptions of epistemology, arguing that the latter is a more malleable construct compared to personality traits. For the purposes of the current study that addressed and essentially compared two theoretical frameworks, the need for an objective term (as objective as a choice of a term can be) necessitated a term that most closely depicted the particular construct. Again, that could be taken to mean that we do have a fair grasp of what personal epistemology is about, but relevant discussions do not seem to concur (see Elby, 2009; Sandoval, 2009). *Personal epistemology* can be considered a relatively objective term being used by researchers working within different, antithetical even, frameworks (Hofer & Pintrich, 1997; Hammer & Elby, 2002) and also general enough avoiding associations with particular frameworks. Operational definitions of the construct vary however. The aim of the next part of the literature review is to describe each theoretical framework and highlight their discrepancies that informed the development of the instructional interventions.

Epistemological Theories Framework

The foundation for the development of this framework was originally laid by Schommer (1990), being the first researcher to divert from the developmental paradigm of her predecessors (e.g. Perry, 1970). As such, Schommer (1990) doubted unitarity and stage-like procession of personal epistemology and suggested instead a belief system comprised of five ‘more or less’ independent dimensions (structure, certainty, source of knowledge, control, and speed of knowledge acquisition) that may develop independently in asynchronous fashion (i.e. certain dimensions may be more advanced and prevalent compared to others).

Hofer and Pintrich (1997) critiqued the inclusion of the latter two dimensions of control and speed of knowledge acquisition arguing that these dimensions refer to beliefs about intelligence (introduced by Dweck & Legget, 1988) and learning, and they are not considered epistemological in nature. According to Dweck and Legget’s theory of intelligence, people’s conceptions of intelligence can be described on a continuum of an entity view of intelligence (intelligence cannot change) to an incremental view (intelligence changes and develops with effort). Moreover, people with an entity view of intelligence consider that learning happens quickly or not all, while people with an incremental view do not consider learning constrained in short-term efforts. Hofer and Pintrich considered these dimensions about learning and intelligence peripheral to the construct of personal epistemology. They proposed instead that the content of personal epistemology be limited to beliefs about the nature of knowledge and knowing, represented in four dimensions: c*ertainty of knowledge* (absolute vs. tentative and evolving), and *simplicity of knowledge* (isolated, unambiguous bits vs. interrelated concepts), that refer to the nature of knowledge; *source of knowledge* (handed down by authority vs. derived from reason) and *justification for knowing (testimony and one step inference vs. scientific method) that* refer to the nature of knowing (King & Kitchener, 1994; Kuhn, 1999; Hofer & Pintrich, 1997).

While separating beliefs about learning from beliefs about knowledge and knowing contributes to conceptual clarity per Hofer and Pintrich (1997), others have recently expressed concerns that doing so jeopardizes the emergent field of personal epistemology by mischaracterizating it. Elby (2009) contended that it is too soon for this field to limit the study of itself only to beliefs about knowledge and knowing, excluding from its examination its intimately intertwined counterpart, beliefs about learning. Replying to Elby (2009), Sandoval (2009) put forward the position that for conceptual and definitional clarity in a field disadvantaged by lack of it, beliefs about learning should not be conflated with beliefs about knowledge and knowing. However, he acknowledged the importance of beliefs about learning and their possible interrelatedness with epistemic beliefs, concluding that beliefs about learning should not be taken out of the picture, but be examined as a separate construct instead. In this study, beliefs about learning and intelligence were considered to be distinct from epistemic beliefs and as such their examination was considered to be beyond the scope of the present study.

In addition to concerns about what the construct of personal epistemology entails, another pressing issue that Hofer and Pintrich (1997) addressed was the form, or the structure of personal epistemology. They suggested that beliefs pertaining to the nature of knowledge and knowing, take the form of a *personal theory* similar to that proposed in conceptual change (e.g. Vosniadou, 1994) and theory of mind research (Wellman, 1988). This means that students' epistemic views conform to three theory prerequisites as outlined by Wellman (1988): (a) coherence among its constitutive ideas and concepts, (b) ontological distinctions among entities and processes in the domain, and (c) affordance of a causal-explanatory framework for the phenomena in the domain. Therefore, Hofer and Pintrich's (1997) definition can be viewed as middle ground between developmental models and models that view epistemology as a system of orthogonal dimensions that do not necessarily combine into a coherent structure (Schommer-Aikins, 2004). This exact characteristic of 'comprehensiveness' or 'cohesion' attributed to epistemology by the use of the term 'theory', is the main disagreement of researchers espousing the epistemological resources framework.

Epistemological Resources Framework

Hammer and Elby (2002) initiated an alternative line of inquiry in the study of personal epistemology, arguing that an assumption of 'unitarity' is evident in approaches that consider personal epistemology as personal theories. Hammer and Elby's (2002) definition of 'unitarity' is different from the stage-like procession of epistemology underlying developmental models; they contend rather, that unitarity is meant to mistakenly impose the form of a coherent cognitive structure or unit onto personal epistemology. In that sense, personal epistemology parallels cognitive structures and thus can be construed as a set of misbeliefs, in the same manner that alternative conceptions about science phenomena are considered misconceptions. Consequently, in line with the conceptual change literature, efforts are directed towards identifying those extant beliefs and *changing* them, replacing them by the experts' opinions. Hammer and Elby (2002) argue that this very act of changing beliefs does not lend itself to a constructivist approach, although it is characterized as such, because as the presume, the raw material from which to build on a more advanced epistemology is available in students. The assumption of unitarity is evident in the use of the term 'beliefs'.

If personal epistemology can be characterized as a system of well organized beliefs, like conceptual structures, that would imply that epistemology is a kind of declarative knowledge, that people can be aware of, and if not, become aware as they complete epistemological measures. Their responses to such measures are used to infer their enacted epistemology in science classroom. Hammer and Elby (2002) argue that this is a faulty assumption, as personal epistemology is tied to particular contexts. The context of classroom science learning is different from the context of a questionnaire. Moreover, unitarity implies that personal epistemology, akin to a trait, be examined like a personality characteristic limiting its evaluation to inferences from aspects of students' preferences about more general tastes and attitudes (i.e. I don't like movies that do not have an ending). Both arguments about the disparity between the two contexts of classroom learning and questionnaire completion as well as the underlying assumption of a trait-like nature of the construct of personal epistemology, concur that views of epistemology as personal theories may mischaracterize personal epistemology mainly because of the way it is decontextualized. Attention to context and context dependence in the study of personal epistemology is the cornerstone of Hammer and Elby's (2002) 'epistemological resources' framework.

According to the epistemological resources framework, personal epistemology is comprised of fine-grained epistemological resources that are analogous to diSessa's (1993) phenomenological primitives (p-primes). According to this view, one's epistemology emerges as these available epistemological resources get activated (sometimes appropriately, sometimes not) in a manner that is sensitive to the context (Hammer & Elby, 2003; Louca et. al., 2004; Rosenberg, Hammer, & Phelan, 2006). This approach challenges views of epistemologies as stable unitary structures such as theories or belief systems that are regarded as traits and that systematically characterize people in different situations. Theorists supporting the resources framework presume that inconsistency is possible even within the same domain. If, for example, students demonstrate an advanced epistemology in history within the context of a small group discussion, it does not necessarily mean that they will also demonstrate this advanced epistemology in a whole-class discussion or in a test in history. They presume that such evidence of students' participation in particular tasks demonstrating advanced epistemologies, supports local coherence that certainly does not generalize within the domain.

Epistemological resources can supposedly comprise primitive, cognitive structures in children's everyday reasoning that can give rise to more complex belief structures. Importantly, like p-primes, resources are smaller but more general units, affording applicability to various situations. Hammer and Elby (2002) suggested that there are epistemological resources for understanding the *nature* and *sources* of knowledge, for understanding epistemological *activities*, epistemological *forms* and epistemological *stances* (these resources can be available even to children as young as three-year olds). For instance, one resource that refers to the nature of knowledge is k*nowledge as propagated stuff,* i.e. knowledge is a kind of stuff that can be passed from one person to the next. Another resource is *knowledge as free creation*, i.e. invention, a routine experience for children and "I made it up", a routine explanation of their ideas. A resource that refers to an epistemological activity is *accumulation* ("finding out", retrieval of information) and another is f*ormation (*like forming rules for games). *Rule systems, facts categories, pictures, songs* etc. are all examples of epistemological forms. Moreover*, belief, disbelief, puzzlement, acceptance, understanding* are all examples of epistemological stances (Hammer & Elby, 2002). These resources are neither correct nor incorrect, but supposedly combine meaningfully depending on the context of activation. For instance, the epistemological activity *formation* may be invoked in conjunction with the epistemological form, *forming rules*. A more advanced personal epistemology may be enacted when a set of productive epistemological p-primes get activated appropriately. Context is deemed to be tremendously important in the process of successful activation.

Implications for epistemological interventions

According to the *Epistemological Theories Framework* personal epistemology is considered theory-like composed of four dimensions that may converge into a coherent structure. Consequently, personal epistemology, akin to conceptual structures about science phenomena, may be difficult to change and thus interventions should focus on challenging students' views. In contrast, according to the *Epistemological Resources Framewor*k personal epistemology is considered fragmented and composed of epistemological resources derived from students' experiences in everyday life. As a result, interventions should utilize such experiences to give rise to activation of productive epistemological resources.

Operational definitions

In a comparative study such as the present that utilized conceptual disparities between two frameworks to design instructional interventions, definitions needed not only to be operational; they also needed to be objective. This was a real challenge however, because as discussed in the previous section, defining terms is almost equal to laying out theoretical orientations. In this study, personal epistemology was defined as students' views about knowledge and knowing. This definition concerns content. With respect to structure or form, instead of trying to do justice to two inherently divergent definitions (theories vs. resources), this study posed a research question instead, aiming to contribute to a better understanding of the issue at hand. The question put forward introduced a comparison of the effectiveness of two instructional interventions that emerged from the two different frameworks in terms of advancing personal epistemology. Therefore, the present study attempted to provide an indirect test of the two theories concerning the structure of personal epistemology by comparing the effectiveness of interventions that originated from each theoretical framework.

Attending to recent calls about the negative connotations of dichotomous characterizations of students' personal epistemology as 'sophisticated' vs. 'naive' that essentially disadvantage students labeled with the latter (Muis, 2004; Hofer, 2008), within the context of the present study, students were considered to have *availing* conceptions (see Muis, 2004) if they tended to believe that knowledge is tentative and evolving (certainty), a complex system of interrelated concepts (simplicity), derived from active personal construction (source) and validated via scientific back and forth inquiry processes (justification).   They were considered to espouse *non-availing* views, if they considered knowledge to be stable and unchanging, a collection of true unrelated facts about the world, derived from authorities and accepted at face value. The term 'availing' (appropriate) denotes the degree to which views about the nature of knowledge and knowing are appropriate for particular learning contexts. The question, then, that the present study asked concerned the extent to which availing views concur among the four dimensions or diverge. Concurrence would imply a theory-like structure, while incongruence would provide support for a manifold fragmented structure.

Mapping resources onto dimensions

The use of the term ‘resources’ disembodies epistemology from the study of the individual mind to sets of primitive epistemological ideas shared among communities of learners (Lave & Wagner, 1991). Viewed from this framework of legitimate participation vs. marginal non-participation (see also Hickey, 1997) epistemology is construed as a set of fine grained resources that if activated productively may facilitate more engaged participation within communities of learners (Rogoff, Baker-Sennett, Lacasa,& Goldsmith, 1995). Resources are thus the building blocks of availing or non-availing emergent personal epistemology that may support students’ engaged participation, that is, their effective and motivated participation in learning tasks.

There is not yet an established list of epistemological resources in children. The types and examples presented in the previous section are only tentative. However, to activate resources one needs to identify them first. Hammer and Elby (2002) suggested heuristics for indentifying promising candidates. Candidate resources must: (a) be possible to identify in young children (b) have plausible developmental origins, and (c) be recognizable as ‘commonsense’ mini generalizations about knowledge. For the purposes of this study, the targeted resources corresponded to the four dimensions that were hypothesized to comprise personal epistemology (certainty, simplicity, source and justification). For instance, resources such as ‘knowledge as free creation’,’ knowledge as fabricated stuff’ and ‘formation’ could simultaneously be activated to alert students about the idea of personal construction (source dimension). The resource ‘accumulation’ (the act of gathering or retrieving information) in conjunction with ‘checking’ (the act of making sure) and ‘doubting’ could be invoked to inform students about the justification of knowledge claims upon collected evidence (doubting). The resource ‘rule system’ could be used to imply the notion of interrelatedness of knowledge (e.g. chess is widely known to be described along with a coherent set of rules).

Per context theories, young children are supposed to use epistemological resources in their everyday routines and reasoning. However, in order to activate them appropriately we needed to know which resources were available to students. Therefore the extent to which particular resources, which could be mapped onto the four dimensions of certainty, simplicity, source and justification, were available to students’ repertoire of everyday thinking, was examined.

Measuring personal epistemology

Personal epistemology is a construct 'notoriously difficult to measure' (DeBacker et al., 2008) but measurement difficulties may be considered to stem from conceptual problems in the field (Limon, 2006). Beyond conceptual disparities between the epistemological theories and the epistemological resources framework presented in the previous section, differences also exist among research conducted under the same frameworks. Ongoing research seems to develop in circles as lack of conceptual clarity, develops into weak measurement efforts that in turn further obscure understandings of the nature of personal epistemology and what it entails. Given the pressing need for clarity in the field (Hofer & Pintrich, 1997; Limon, 2006) informed instrumentation decisions were required.

The use of surveys and questionnaires has been the most widely used instrumentation approach in research conducted under the epistemological theories framework. Another instrumentation method used in research conducted under this framework has been the use of interviews. Theorists supporting the epistemological resources framework however, criticize the use of questionnaires and interviews, arguing that such methods decontextualize personal epistemology and as a result, derived data mischaracterize the nature of students' beliefs (Elby & Hammer, 2001). They support triangulating questionnaire data with qualitative data derived from clinical interviews, videotaping and discourse analysis. It is argued however, that there are also notable conceptual disparities within research conducted under multidimensional frameworks as those were described in the previous section. Such disparities influence operational definitions of the construct of personal epistemology that are subsequently reflected in measures developed to assess it. As a result, the hypothesized multidimensional structure of personal epistemology has not been consistently supported in empirical studies.

Inconsistent multidimensional structure in current instruments

Existing instruments that evolved from multidimensional frameworks suffer both conceptually and methodologically. A paramount problem that surfaced in almost every study conducted under a multidimensional framework was that the number and meaning of the hypothesized dimensions failed to replicate in subsequent studies. Novel factors usually emerged with overall low reliabilities. DeBacker et al. (2008) reviewed research on personal epistemology focusing on studies that used three well-known personal epistemology instruments: the Epistemological Questionnaire by Schommer (1990), the Epistemological Beliefs Inventory by Bendixen, Schraw and Dunkle (1998), and the Epistemological Beliefs

Inventory by Wood and Kardash (2002). That review provided insights about main underlying problems for each.

The Epistemological Questionnaire (EQ) consisting of 63 items, represented in 12 subscales hypothetically comprising five dimensions proposed by Schommer (1990), was the first multidimensional instrument to be introduced and as such has been the most widely used instrument. Schommer (1990) originally proposed five orthogonal dimensions: (a) certainty, (b) simplicity, (c) omniscient authorities, (d) ability is fixed, and (e) learning occurs quickly or not at all. Schommer's (1990) analysis showed that only a four factor solution could be empirically confirmed as the omniscient authority dimension did not emerge. Similarly, subsequent studies by Schommer and others (e.g. Schommer, 1993; Clarebout, Elen, Luyten, & Bamps, 2001) replicated four factor solutions labeled with the same terms but conceptually dissimilar from the original dimensions, as the grouping of subscales under each dimension was different. Even the number of dimensions differed as studies found that three-factor solutions fit the data (Quian & Alvermann, 1995). DeBacker et al. (2008) attributed this problem to sample-specific scoring procedures to be delineated in a subsequent section along with other methodological problems.

Replication problems with the EQ led researchers to adaptations and even radical modifications of the EQ that essentially resulted in new instruments. Bendixen, Schraw and Dunkle (1998) created the Epistemological Beliefs Inventory (EBI) with new items to better capture the five dimensions proposed by Schommer while paying attention to preserve the 'omniscient authority' dimension (source of knowledge) that although it was originally introduced by Schommer, it was not empirically supported in her studies (Schommer, 1992; 1993). EBI consists of 32 items grouping into five 'clean' factors as the authors contend: (a) simple knowledge, (b) certain knowledge, (c) omniscient authority, (d) quick learning, and (e) fixed ability. However, despite that Schraw, Bendixen and Dunkle (2002) replicated the five factor structure of EBI, Naussbaum and Bendixen 's (2002) factor analysis of EBI on a different set of data yielded only two factors, complexity and uncertainty. It must be noted that subscale grouping under these two dimensions does not necessarily converge conceptually. For instance, the subscales 'certainty of knowledge' and 'omniscient authority' group together under the uncertainty factor. However, it is somewhat problematic to reason how students' views about the sources of knowledge (knowledge is derived from external authorities, vs.

knowledge is actively constructed) contribute to measurement of the uncertainty of knowledge (knowledge is unchanging vs. knowledge is tentative).

Wood and Kardash (2002) combined items from Schommer's (1990) EQ and Jehng, Johnson, and Anderson's (1993) instrument to create an 80-item survey, the Epistemological Beliefs Survey (EBS). After tests of internal consistency and exploratory factor analyses thirty-eight items were retained, and they represented five subscales: speed of knowledge acquisition, structure of knowledge, knowledge construction and modification, characteristics of successful students and attainability of objective truth. Speed of knowledge acquisition supposedly corresponds to Schommer's quick learning dimension, while structure corresponds to simplicity of knowledge. The remaining three factors were novel. Replication efforts of this instrument are not known, while reported internal consistency indices are generally low (DeBacker et al., 2008).

Difficulties in providing empirical evidence to support a consistent multidimensional structure across studies direct attention to conceptual disparities in defining personal epistemology that are inevitably reflected in measurement and instrumentation efforts. It is argued here that inconsistency regarding the structure and content of personal epistemology seem to involve three major problems: (a) incongruence about what personal epistemology is and what it entails, (b) incongruence about the domain specificity of personal epistemology and its manifestations in existing instruments, and (c) problematic analytic procedures. Each of these issues will be discussed next in order to underline problems with existing instruments that were used to inform the instrumentation efforts of the current study in measuring 11 year olds' epistemology in science.

Incongruence about what personal epistemology is and what it entails

Should beliefs about learning be considered part of personal epistemology? Researchers have not yet reached consensus in defining personal epistemology and as such, some researchers (Schommer, 1990; Schommer-Aikins, 2004; Hammer, 1994; Elby, 2001; 2009) include beliefs about learning in their research, while others (Hofer & Pintrich, 1997; Sandoval, 2005; 2009) do not. Schommer (1990) was the first researcher who departed from prominent developmental models of the time and suggested a multidimensional framework, hypothetically composed of five dimensions, two of which pertained to views about learning. Hofer and Pintrich (1997) however, argued that beliefs about learning are considered peripheral in personal epistemology and as such they should not be examined within the context of studies on personal epistemology. They presumed that beliefs about learning are not epistemological in nature and for the sake of clarity in the field they should not be examined as part of personal epistemology.

Hogan (2004) and Sandoval (2005) identified one possible shortcoming of existing instruments related to the distinction of formal epistemology from practical or process epistemologies. Formal epistemology refers to students' ideas about scientific knowledge and scientists' efforts and represents the epistemology that current instruments purport to measure. As Sandoval (2005) argues, formal epistemology is a distal measure of students' personal epistemology because it refers strictly to scientists' work and fails to elicit students' views about their own efforts in learning science that perhaps impact their learning and inquiry processes. The latter is termed practical epistemologies and it is considered a bridge towards formal epistemology. As such, according to Sandoval (2005) practical epistemologies should be purposefully examined and not extrapolated from responses to instruments tapping formal epistemology.

In essence, what Sandoval (2005) argued, which concurred with Hofer and Pintrich (1997), was to disentangle an obscure construct into its identifiable elements. In other words, views about learning (practical epistemologies) should be treated as a distinct entity from views about the nature of knowledge and knowing (formal epistemology). Recently, Elby (2009) critiqued the distinction of the two constructs arguing that it may be a fabricated distinction, obscuring than elucidating the construct of personal epistemology. He contended that it is too soon for such a relatively new field to proceed to such distinctions, because dropping views about learning from investigations of personal epistemology may cause greater confusion. In the hopes of understanding the nature of personal epistemology, Elby (2009) made a case of retaining views about learning in future investigations. In response to Elby's (2009) commentary article, Sandoval (2009) acknowledged the possible contribution of views about learning to the impact of personal epistemology and argued that views about learning should not be undermined nor unexamined. He suggested instead that they be examined but be treated as a separate construct.

Incongruence about the domain specificity of personal epistemology and its manifestations in existing instruments

The particularities of each knowledge domain should be reflected in individual subscales as well as items. For instance, the use of experiments in deriving evidence to justify knowledge claims constitutes a critical subscale that should be included in instruments claiming a focus on science. Unfortunately, studies examining domain specific personal epistemology adapt on the surface existing general epistemology instruments. That is, the instructions at the beginning of the instrument require respondents to focus on the particular domain of interest and adhere to that domain as they respond to the total of items. To further support the argument that adaptations are only minor, it should be noted that studies that compare students' beliefs across domains, may use the same instrument on a single administration, asking students to respond to the same set of items while keeping another domain in mind (e.g. Hofer, 2000). Muis et al. (2006) criticized such approaches as being highly misleading in terms of validity: how do we know that indeed students keep that particular domain in mind (especially when some items are as broad as 'I don't like movies that don't have an ending' or 'Scientists can ultimately get to the truth'). How should these items be interpreted in the context of a mathematics survey for instance?

DeBacker et al. (2008) reviewed studies examining epistemology at a domain specific level and found that overall low consistency indices persisted, concluding that domain specificity is not the sole problem in current instruments. However, as Muis et al. (2006) argued domain specificity should be reflected at the item level as well. Moreover, it is argued that domain-specific items should subsequently group into subscales that are meaningful in the domain under study. In other words, the idiosyncratic nature of knowledge and especially of knowing of each domain should be reflected in the subscales that comprise dimensions.

An inherent confound in current measures that may also hinder the potential of reliable and valid measurement of personal epistemology is that within the same instrument there are both items that require responses in regard to scientists' ideas and items that ask students to reflect on their ideas in science (Muis et al., 2006). This concern may further support the argument by Sandoval (2005; 2009) and Hofer and Pintrich (1997) that a distinction should be drawn between students' own views and efforts in learning science on the one hand and scientists' ideas and inquiry practices on the other.

Analytic procedures

Reliability. In their overview of EQ, EBI and EBS DeBacker et al. (2008) presented the alpha coefficients reported by related studies to highlight the serious reliability problems of these instruments. Duell and Schommer-Aikins (2001) stated that reliability coefficients for the EQ ranged from .55 to .70 for middle school students, from .51 to .78 for high school students and from .63 to .85 for college students, while Schommer-Aikins et al. (2002) reported reliabilities from .58 to .73 in the domain specific versions of the EQ. Bendixen et al (1998) reported reliability estimates from .58 to .68, while reliabilities reported from Wood and Kardash (2002) ranged from .58 to .74.

Morever, as DeBacker et al. (2008) argued subsets may also suffer from low internal consistency with indices indicating that the particular grouped items measure less than half of the variance. This further obscures the meaningfulness of the comprised dimensions and DeBacker et al. (2008) expressed serious concerns about the implications of such reliability problems in studies that claim correlation of personal epistemology with constructs related to learning, motivation and achievement. Moreover, they expressed a concern that as novel factors emerge, researchers are essentially using different instruments across studies and this should raise concerns about comparisons between outcomes of different studies.

Type of factor analysis. DeBacker et al. (2008) presume that sample-specific procedures for analyzing data derived from multidimensional instruments are problematic. Schommer (1990) analyzed the EQ using the 12 subset scores as individual scores in Exploratory Factor Analysis (EFA) instead of the individual 63 items. This approach is considered problematic because the hypothesized four factor structure is imposed to data as individual items are not allowed to vary. This technique is widely used in the domain of personal epistemology with few exceptions (e.g. Jehng et al., 1998; Quian & Alvermann, 1995). Moreover, factor analyses techniques were used despite the relatively small samples.

Confirmatory Factor Analysis (CFA) may be a more appropriate technique because it is guided by theory and provides a more stringent test of the hypothesized multidimensional structure. Thus, DeBacker et al. (2008) used the three aforementioned instruments in three consecutive studies using large sample of undergraduate students, merged from different universities and recruited from educational psychology classes. A total of 935 undergraduate students completed the EQ that was further factor analyzed using CFA. Outcomes revealed that only a two-factor solution fit the data well (neither item level nor subset level analysis replicated Schommer's four-factor structure). Only six interpretable subsets emerged that cohered into two dimensions related to views about learning. Subset and dimension reliabilities were low. A similar pattern was revealed in the analyses of the EBI and the EBS. The five factor structure of EBI was not a good fit to the data and alphas were uniformly below .70, while the EBS five factor structure (N=415) fit the data marginally well and reliabilities were low, while correlations between latent variables raised questions about the hypothesized orthogonality of epistemological dimensions (N=417).

In summary, conceptual and methodological shortcomings of current instruments necessitate the design and development of domain-specific instruments rigorously guided by well articulated theoretical frameworks. Domain specificity should be reflected both at the item-level and the subscale level. The latter should be meaningful entities that reveal aspects of the nature of knowledge and knowing in the domain of interest. Stathopoulou and Vosniadou (2007) developed a Greek physics-specific epistemological questionnaire. The Greek Epistemological Beliefs Evaluation Instrument for Physics (GEBEP) consists of 40 likert-scale items (on a scale 1-5), nine debate items identified into 10 subscales pertaining to four hypothesized and partially confirmed dimensions: a. structure, b. stability, c. source and d. justification. Based on the work of Smith et al. (2000) and Driver et al. (1996) and others, Stathopoulou and Vosniadou strived for a physics-specific instrument that reflected the nature of physics knowledge as well as culture-specific aspects of physics learning amongst Greek students. Moreover, they considered beliefs about learning distinct from personal epistemology and therefore they did not examine them. Data were gathered from 372 10th graders (15 year old students). Overall reliability of the instrument reached a Cronbach's alpha of .72. Exploratory factor analysis at the item (not subset) level yielded a four-factor solution involving 25 items explaining 26% of variance which as the authors argued is rather common for this kind of analysis: (a) structure of knowledge (piecemeal collection of facts vs. a system of well organized elements theoretical in nature; Cronbach's alpha=.67), (b) construction and stability of knowledge (knowledge is acquired via straightforward and unquestioned procedures and once acquired is not subjected to change; alpha=.56), (c) attainability of absolute truth (knowledge develops, approximates and becomes identical with absolute truth; alpha= .66), and (d) source of knowledge (no further information was reported for this dimension). The dimension justification of knowledge did not emerge. This was attributed to the fact that Greek students have very little experience and therefore are not used to conducting their own experiments to test their ideas (Stathopoulou & Vosniadou, 2007).

However, despite Stathopoulou and Vosniadou's (2007) argument in favor of distinguishing views about learning from views about knowledge and knowing, they did not attend to the concern expressed by Muis et al. (2006) that items should relate to scientists' views and not to students' views and included items such as ' How much physics knowledge we get from school depends mostly on the quality of our teachers', or 'A really good way to understand a physics textbook is to reorganize the content in your own way'(note that such confounds are particularly evident in the source dimension, perhaps due to encompassing meaning of this dimension related to how one pursues knowledge, that could also be easily applicable to students' approaches in science). It is argued here that in order to develop focused instruments on students' views about the nature of scientific knowledge, views about their own efforts in doing science (which is distinct from views about learning speed and ability) should be disaggregated.

Adhering to the concerns expressed by DeBacker et al. (2008) and Muis et al. (2006) a second goal of the proposed research was to design and develop a science-specific self-report instrument, appropriate for sixth grade students (11-12 year olds) in terms of language and content level used in referred examples. The overall structure of 10 subscales was adapted from the GEBEP, while new subscales were created to sufficiently depict the particular dimensions of certainty, simplicity, source and justification. Only a few items were retained in their exact phrasing, as the majority of items included in the GEBEP were considered difficult for sixth grade students. Moreover, scenario-based items were considered to measure personal epistemology implicitly, while statements were considered to tap explicit epistemic views. As such, the analysis distinguished between these two different types of questions and did not merge them as Stathopoulou and Vosnadou (2007) did. Per Gill et al. (2004), statement items are considered a distal measure of personal epistemology, while scenario-based items are considered a proximal measure because they tap epistemic views indirectly and informally, without requiring students to articulate their views. It was consequently reasoned that expected effects of instructional approaches on personal epistemology would be more pronounced on students' implicit views.

Impact of Personal Epistemology

The significance of the present study stems from its focus on promoting personal epistemology, a construct that is considered to be related to how people learn. In order to support this claim and highlight the importance of personal epistemology, this section of the literature review aims to present research that seeks to clarify directional relationships, focusing on the impact of personal epistemology. In particular, the review will summarize research that examined aspects of cognition, motivation and academic performance in relation to personal epistemology.

Cognition

A significant amount of learning in schools is considered to take place through reading texts. Research in personal epistemology provides evidence that the quality of learning taking place through reading is related to students' personal epistemology. In a study examining the impact of epistemology on comprehension, Schommer (1990) asked undergraduate students to read expository texts either on competing theories on aggression or controversial issues on the B-6 vitamin. The texts did not have a concluding paragraph and students were required to write it. Students rated their confidence in understanding the text, wrote a conclusion and completed a mastery test (multiple choice questions asking for the recognition and application of main ideas in the passages). Results indicated that the more students believed in certain knowledge, the more likely they were to write inappropriate absolute conclusions. Conclusions derived from a text are related to the situation model of a text that, as it will be presented in a subsequent section, it is critically related to learning from text. The study also found that beliefs in quick learning, predicted oversimplified conclusions. However, in order to accurately describe the impact of personal epistemology it is useful to distinguish effects related to learning beliefs from effects related to dimensions strictly referring to the nature of knowledge and knowing. While effects related to simplicity of knowledge were not detected in Schommer's (1990) study, Schommer, Cruise and Rhodes (1992) determined that the less undergraduate students believed in simple knowledge, the better they performed on a mastery test and they more accurately assessed their comprehension of a statistical text.

Beyond comprehension outcomes, personal epistemology seems to also impact comprehension strategies. Dahl, Bals and Turi (2005) examined whether epistemic beliefs were related to students' self-reported use of text comprehension strategies. The more students believed that knowledge was integrated and organized as complex networks, the less they tended to report using rehearsal strategies and the more they tended to report using organization strategies to draw connections among pieces of text. Moreover, the more students believed in fixed knowledge the less likely they were to report using elaboration and critical thinking strategies. The more students believed in simple and certain knowledge, the less likely they were to report using metacognitive and self-regulation strategies. These findings are also supported by the findings of Hofer (2004) who conducted a series of think alouds of students' online searching for a simulated science assignment to track evidence of the four dimensions of epistemology and of epistemic metacognition (i.e. evaluation of learning strategies in regard to the adequacy of gathered information). For example a student reported that a book published in 1908 would be adequate to learn about a biology topic because "in biology when they know it, it's not likely to change" (p. 53). Hofer regarded this statement as evidence of belief in simple and certain knowledge and of little metacognitive monitoring (i.e. the student was not motivated to search any other sources of information, select, relate and organize information because of a judgment that a book of 1908 was simply appropriate and adequate).

In a similar effort to examine personal epistemology in a particular learning context and collect evidence of the four hypothesized dimensions in students' spontaneous reflections about knowledge and knowing Mason, Ariasi, and Boldrin (2011) examined personal epistemology during online information searching. High school students were asked to search online information on the controversial topic of the health hazards concerning the continual use of cell phones. Students were asked to think aloud while information searching. Results supported the presence of the four dimensions of certainty, simplicity, source and justification although the majority of students' spontaneous reflections concerned the source of knowledge and the credibility of information sources in particular. Two patterns of epistemic beliefs in action were identified in students' verbalizations: the first pattern represented the evaluation of the credibility of sources and the justification of knowledge, while the second regarded only the evaluation of the credibility of sources. Students whose epistemic reflections were grouped under the first pattern, besides evaluating the authoritativeness of the information sources, acknowledged also the importance of using scientific evidence to support knowledge claims. In terms of learning the important aspects of the issue of health hazards related to heavy use of cell phones and comprehending the inconclusiveness of the available information students whose epistemic reflections were categorized under the first pattern, outperformed students whose reflections were categorized under the second pattern. These results underlined the importance of advanced personal epistemology in cognition and learning in web-based settings.

Besides impact on comprehension outcomes and strategies, there is evidence that supports the influence of personal epistemology on on-line (while reading) cognitive processes. In a study by Kendeou, Muis, and Fulton (2011) undergraduate students read a refutation text about Newtonian physics and were asked to think aloud while reading. After reading the text they were instructed to free recall the text information. The study indicated that students who viewed knowledge as constantly evolving and subjected to questioning engaged significantly more in conceptual change processes as opposed to students who viewed knowledge as certain and accepted at face value. Findings from this study illustrate that beliefs in the tentative nature of knowledge enhance the on-line conceptual change and comprehension processes. The relationship between personal epistemology and conceptual change has been previously supported. Quian and Alvermann (1995) examined the relationship between learned helplessness, epistemic beliefs and conceptual change learning. They concluded that the impact of epistemic beliefs on learned helplessness was inconclusive, while they found that belief in simple-certain knowledge and quick learning did not facilitate students' engagement in conceptual change processes.

Motivation

Braten and Stromso (2004) also examined the contribution of epistemic beliefs and implicit theories of intelligence to the adoption of mastery, performance-approach and performance avoidance goals of student teachers participating in an innovative instructional context. The results indicated that belief in quick learning (learning occurs quickly or not at all) predicted adoption of performance avoidance and performance approach goals while it did not predict adoption of mastery goals. Students who believed in stable knowledge (knowledge does not develop) were less likely to adopt mastery goals.

Muis and Franco (2009) examined a model of self-regulated learning in which personal epistemology and goal orientation were considered critical variables providing consistent evidence with Braten and Stromso (2004) in regard to goal orientation. Two hundred undergraduate students enrolled in an educational psychology course were given photocopies of class assignments and midterm questions and were asked to write their perceptions about those tasks. They were subsequently required to complete three questionnaires, each related to the constructs under investigation: a domain-specific epistemological beliefs questionnaire, a learning and metacognitive strategies questionnaire and an achievement goal questionnaire. Students' grades on course assignments and exams were used as evidence of their achievement in the course. With regard to the impact of personal epistemology on achievement goals, results indicated that students who believed that knowledge in educational psychology was simple and certain were more likely to adopt performance approach goals (demonstrating competence or avoiding failure) and less likely to adopt mastery approach goals (focusing on learning). Moreover, results confirmed the hypothesis that achievement goals impact learning and metacognitive strategies. A mastery-approach orientation positively predicted the use of three deep level processing strategies and the use of a rehearsal strategy. In summary the results of this study indicate that personal epistemology influences goal orientation which subsequently affects learning and metacognitive strategies.

Academic achievement

Schommer (1993) examined undergraduate students' personal epistemology in relation to their academic achievement (GPA) and found that the less students believed in quick learning the higher the GPA they earned. In this study Schommer (1993) expressed an assumption about the impact personal epistemology exerts on achievement via the use of learning strategies that Cano (2005) put to the test. About 1600 students, aged 12-20 years old, completed an epistemology inventory along with a learning processes questionnaire that tapped students' self-reported use of learning strategies. An average of the end of the year grades for all subjects was used as an index of achievement (academic performance). Findings confirmed the hypothesis that personal epistemology impacts academic achievement through the selection of learning strategies (Cano, 2005). The study also provided evidence of a direct impact of epistemology on achievement and confirmed previous findings about the impact of personal epistemology on achievement (Hofer 2000, Schommer, 1993).

More related to the focus of this study on science, Stathopoulou and Vosniadou (2007) developed and validated a Greek version of a physics related epistemic beliefs inventory and subsequently examined the impact of physics-related epistemology on conceptual understanding in physics tapped with a measure in Newtonian dynamics. Results indicated that an advanced physics-related epistemology significantly predicted conceptual understanding of Newtonian physics. Importantly, epistemology was shown to be a better predictor of physics conceptual understanding compared to school grades.

Carey and Smith (1989) argued that in science children hold a common sense epistemology; that is they see knowledge arising unproblematically from sensory experiences and as the collection of many true beliefs. Young children do not see the necessity of an interpretive framework or theory. This 'unproblematic' epistemology however, is at odds with the constructivist epistemology that is considered appropriate for science learning. Science learning thus can be hindered by such epistemologies. Carey and Smith (1989) argued that this unproblematic epistemology may be the result of children's difficulties to construct scientific arguments from experimental results. Moreover it could be due to their difficulties in designing experiments and in drawing conclusions from experimental evidence and in distinguishing theory from belief.

In science learning, argumentation is deemed to be a significant skill (Driver, Leach, Millar, & Scott, 1996). Nussbaum and Bendixen (2003) examined the effect of personal epistemology, along with a set of other cognitive and personality variables, on undergraduate students' disposition to engage in argument. Belief in simple and certain knowledge predicted the disposition to avoid arguments, as opposed to approach arguments. This finding carries some implications regarding students' dispositions in 'argumentativeness'. Taken together with Carey and Smith's (1987) interpretations about students' difficulties in reasoning about experimental data, these results may suggest that young students' scientific reasoning skills are hindered by their beliefs in certain and simple scientific knowledge.

In summary, personal epistemology impacts cognition, motivation and achievement at multiple levels. Personal epistemology has been found to influence comprehension processes, outcomes and strategies. Belief in simple and certain knowledge hinders the process of drawing appropriate conclusions from text and as a result affects learning from text. Moreover, belief in the certainty of knowledge does not facilitate the adoption of mastery-approach goals (engaging in learning for the sake of learning). Personal epistemology is a better predictor of science learning compared to academic achievement and seems to influence the underlying processes of scientific reasoning via argumentation.

Factors that impact personal epistemology

A substantial part of research in personal epistemology aims to delineate factors that impact personal epistemology. Findings from these studies however, remain largely inconsistent and inconclusive. This lack of consistency in studies that examine age, gender, educational level, field of study, SES and other family background variables (e.g. parents' educational level and employment status) could be a reflection of the measurement difficulties that challenge this field of study. As it will be discussed in a subsequent section, measurement of personal epistemology has been defined and examined in largely inconsistent ways and this might have resulted in perplexing outcomes. Acknowledging that the distinction of beliefs about knowledge from beliefs about learning contributes to a better understanding of the construct of personal epistemology, this distinction will be attempted in the current review wherever possible.

There are two overall trends in research that examine factors that shape personal epistemology: studies that examine factors that impact personal epistemology as it naturally develops with age and studies that examine attempts to purposefully advance personal epistemology (interventions). The purpose of this section is to review both, but focus on the second group of studies that informed the design of the instructional interventions.

Precursors of personal epistemology

Schommer (1990) was one of the first researchers who attempted to examine a spectrum of factors that seemed to relate to personal epistemology. She examined a number of student characteristics and family background variables for 117 junior college students and 149 university students using a survey of student characteristics. The survey requested information about age, gender, year in school, parents' occupation, and parents' education. In addition, a number of items assessed students' upbringing in terms of three categories: (a) characteristics of family structure (e.g., single parent), (b) adherence to rules (e.g., enforcement of strict rules), and (c) encouragement toward independence (e.g., making decisions for oneself). These variables along with verbal ability were categorized into five blocks of variables: (a) social/personal (e.g., age, gender), (b) cognitive (year in school and verbal ability), (c) educational atmosphere and opportunity (e.g., parents' highest education and highest occupational prestige score), (d) encouragement toward independence variables (e.g., allowed to voice opinion and question parents' decisions), and (e) adherence to rules or guidelines (e.g., family strictness to rules and religion). Regression analyses for each of the five blocks on the four factor structures of innate ability, quick learning, simple knowledge and certain knowledge (note that the first two factors represent views about learning) revealed that students' background variables predicted personal epistemology to a certain extent. The influence of the examined background variables was more pronounced on simple knowledge and quick learning while it did not impact certain knowledge: age predicted innate ability (junior college students believed more in innate ability compared to undergraduate students) and gender predicted quick learning (women believed more in gradual learning) (both are views about learning). Verbal ability, highest parental education, encouragement toward independence and adherence to strict rules significantly predicted belief in simple knowledge. The higher verbal ability, parental education and encouragement toward independence, the less students believed in simple knowledge, while the higher the adherence to strict rules, the more students were to believe in simple knowledge. The only variable that predicted certain knowledge (referring to junior college students) was the number of classes completed in higher education. The more classes students had completed in higher education the more likely they were to believe that knowledge is tentative. Thus, an important implication derived from this study is that exposing students to more advanced knowledge that is inherently more tentative facilitates the development of a belief in the uncertainty of knowledge. Moreover, more educated parents seem to encourage their children towards independence of thought and action. In a recent study, Cano and Cardelle-Elawar (2008) indicated that parents' educational level and intellectual climate of the family impacts quick and effortless learning. While this second study seems to support the finding that family intellectual climate may impact personal epistemology, it should be noted that relates to beliefs about learning.

In a subsequent study, Schommer (1993) examined epistemological development and its impact on academic performance of secondary students in relation to gender and grade. Beliefs in simple, certain and quick learning decreased from freshmen (1st year) to senior year (4th year) and girls were less likely to endorse quick learning and fixed ability. This study replicated to a large extent results of Schommer's (1990) study that found that certainty and simplicity, which are strictly epistemological dimensions, are influenced by years in education (exposure to more advanced knowledge encourages more availing beliefs). The study also replicated the previous finding that women were less likely to endorse quick learning.

Results from studies that examine gender effects are generally inconclusive. Pioneering work by Perry (1971) who studied college students' experiences during college with a sample that was gender biased (women were misrepresented), followed by the work of Belenky et al.'s (1989) as a response to Perry's work, (Womens' way of knowing), indicated that there are gender differences in epistemological thinking. In response to Perry's (1971) work that focused on male students and Belenky's et al (1989) study that explicitly examined females' views, Baxter Magolda (2004) examined both males' and females' views and indicated that gender effects found in the two previous studies were a function of methodology and misrepresentation of either gender in each study. Perry mainly studied male perceptions and Belenky's sample consisted strictly of women.

This pattern of mixed results is also evident in research conducted under multidimensional paradigms. Hofer (2000) studied undergraduate students' personal epistemology in science and psychology in relation to gender and provided evidence that students were more likely to see knowledge in science as certain, simple and unchanging compared to knowledge in psychology (Hofer, 2000). Moreover males expressed greater beliefs about the certainty and simplicity of knowledge and viewed authority as the source of knowledge. Bendixen et al. (1998) also found a gender effect in regard to the certainty of knowledge indicating that female undergraduate students espoused more availing beliefs than male students.

Mason, Boldrin, and Zurlo (2006) provided evidence that gender, grade level and curriculum (branches in high school such as science studies and technical-commercial studies) influenced students' transition from a naïve (non-availing) epistemology to a more sophisticated (availing) epistemology. Boys, 8th graders, and students following a science curriculum showed more absolutist positions than girls, 13th graders and students following a technical-commercial curriculum.

In a recent study Ozcal, Tekkaya, Sungur, Cakiroglu, & Cakoroglu (2010) investigated personal epistemology in science of 1152 eighth grade Turkish students in relation to SES and gender. Personal epistemology was examined with the Scientific Epistemological Beliefs Inventory that consists of dichotomous items referring to fixed vs. tentative views of science. Regression analyses replicated the finding of previous studies that parents' educational level and home intellectual environment (working mother, educated parents, number of books at home, own study room) correlates with more tentative views. Contrary to previous studies, in this study boys were more likely to endorse tentative beliefs. Ozcal et al. (2010) argued, gender differences could be a culture-dependent effect. However, this result should be interpreted with caution as indicated by the small effect size.

Chen and Pajares (2010) examined Grade 6 science students' implicit theories of ability in relation to personal epistemology, academic motivation and achievement. They found that after examining all variables, boys and girls differed in only one factor: boys were more likely than girls to report stronger beliefs about the incremental nature of ability in science, but the effect was not particularly strong. Race seemed to impact certainty and simplicity of knowledge; both Asian and Hispanic students were more likely to endorse more advanced beliefs about the source of scientific knowledge compared to Caucasian or African American students. In terms of gender effects, Chen and Pajares (2010) argued that the relatively small difference between boys and girls, only on incremental views, seemed to support Pintrich's (2002) argument that gender differences are non-existent and that gender occasional effects are due to measurement issues.

Conley et. al. (2004) studied change in epistemic beliefs of fifth grade science students over the course of a nine-week science unit and provided evidence of change in the source and certainty dimensions of the epistemological belief system. Also, they found that low SES and low achieving students had less sophisticated beliefs in comparison to average SES and high achieving children. However, there was no evidence that SES and achievement level moderated change in students' epistemic beliefs (no interactions were present). Gender and ethnicity had no impact whatsoever.

This section reviewed studies that mainly examined factors such as educational level, gender, SES, ethnicity and home intellectual environments. It should be noted however that reported results related to differential samples in regard to age (elementary students vs. college students), different conceptualizations and operationalizations of the construct of personal epistemology as reflected in a variability of measures, and culture (studies conducted in USA or elsewhere). Gender differences were found for both views of ability and epistemic views, but in some studies females were found to be holding more availing beliefs, while others indicated the reverse. A relatively robust finding is that home intellectual environment with regard to parents' educational background, occupation and approach to children upbringing significantly influences the degree of availing beliefs children exhibit. An interesting finding is that exposure to more advanced knowledge facilitates epistemological advancement. As students progress through the college years, despite the fact that the degree of change is small (Schommer, 1990), they begin to endorse to a greater extent the belief that knowledge is complex and tentative. Why wait until the college years then? This finding has led researchers to wonder whether informing younger students about the complexity of knowledge may facilitate their epistemological advancement (Schommer, 1990; Pajares, 1992; Hofer, 2004). The present study examined this particular argument: Could instructional interventions foster epistemological advancement in the late years of grade school?

Interventions to advance personal epistemology

As this line of inquiry is just beginning to emerge, there are only a few intervention studies, particularly in the age group of 10-12 years old. Thus, efforts in designing interventions for younger students may be informed from ongoing research with adult participants. In considering findings and implications from research with older students, age differences need to be taken into account. A second important aspect that needs to be considered is the framework researchers use because it shapes advancement conceptualizations. Thus, operational definitions of researchers regarding the process of acquiring or developing more availing epistemic views carry theoretical implications. As previously discussed (see multidimensional frameworks) researchers who use the term *change* imply a theory-like structure of personal epistemology, while researchers who object to theory-like characterizations of personal epistemology avoid the use of a particular term altogether; they refer rather to successful activation of appropriate resources. Due to the aim of this study to compare two theoretical frameworks with respect to personal epistemology advancement, terms are operationally defined, to the degree possible, objectively. Thus the process of acquiring more availing (appropriate) views regarding the nature of knowledge and knowing is defined as *advancement of personal epistemology*.

Interventions to change personal epistemology. In science education research, interventions have varied from long term to short term. Smith et al. (2000) reported on research concerned with transcending classroom culture towards a community of learners (Brown & Campione, 1994) where authentic inquiry practices are at the center of the curriculum. Sixth grade students were encouraged to express, test and revise their ideas, through experimental processes. Experiments thus, were not prescribed by the curriculum or the teacher but they represented authentic inquiry efforts designed by the students to test their own ideas. Ideas and authentic discourse development were therefore the end goal of this constructivist curriculum, as opposed to content coverage and memorization of static facts about science prescribed by more traditional curriculums. In this study, Smith et al. (2000) described a long-term intervention of a single science teacher that consistently trained her students from grade 1-6 to express, discuss and put to the test their ideas about science phenomena. This sixth grade classroom, labeled as the constructivist classroom, was compared to an analogous sixth grade classroom taught by another teacher throughout elementary school. This class, the comparison classroom, followed a traditional curriculum with emphasis on memorization of facts and rules and on conducting prescribed experiments. Researchers examined students' epistemology in science using the Nature of Science Interview developed by Carey and Smith (1989). Students were individually interviewed for about 30 minutes and were probed to respond to statements regarding their views about the goals of science, the nature of scientific questions, the purpose of experiments, the role of ideas in scientists' work and the nature of the processes by which scientific ideas change.

These core interview questions formed four broad themes that Smith et al. (2000) used to analyze and compare students' responses in the two classrooms.

Smith et al. (2000) provided evidence that students in the constructivist classroom considered that the goal of science is to understand and develop new ideas. In sharp contrast, students in the comparison classroom considered that science aims to do things and gather information. None of the students in this classroom reported any notions related to the understanding and the development of ideas. With regard to the nature of scientific questions, the majority of students in the constructivist classroom reported that scientists ask questions derived from theories, seeking explanations of phenomena and also metacognitive questions. The majority of students in the comparison classroom however, reported that scientists ask procedural, journalistic and variable relation questions. Moreover, responding to questions about the nature and purposes of experiments, constructivist classroom students emphasized the testing and developing of new ideas through experiments, while students in the comparison classroom reported that experiments are conducted to find cures or find answers. Similarly, in terms of the role of ideas in scientists' work and the nature of the processes by which scientific ideas change, students in the constructivist classroom revealed an appreciation of effort for development of ideas, that ideas develop in light of new evidence and as an emerging need to derive better explanations of phenomena. Moreover they thought that development of new ideas is constrained by previous knowledge. Most of the students in the comparison classroom replied that scientists keep or abandon an idea on a whim based on a single experiment or observation, while the majority of their counterparts in the constructivist classroom replied that change occurs because ideas develop. Importantly, none of the students in the constructivist classroom attributed change to keeping or abandoning ideas on a whim, while none of the students in the comparison classroom responded that change is constrained by prior ideas (Smith et al., 2000).

This study by Smith et al. (2000) provided rich evidence that elementary school children are capable of epistemological thought well beyond what developmental models would suggest (Inhelder & Piaget, 1958). On the basis of their results, the authors rejected the idea of an underlying constraining developmental factor and attributed students' capability to engage in authentic science and inquiry discourse to a classroom culture that supports and encourages such discourse practices. Their analysis also provided evidence of consistency and coherence among students ideas expressed throughout the four question themes: the goals of science; the nature of scientific questions; the purpose of experiments; the role of ideas in scientists' work and change processes of scientific ideas (Smith et al., 2000). However, despite the rich evidence provided by the study that 11-12 year old students may reason about the nature of knowledge and processes in scientific inquiry, the long duration of the intervention may be discouraging for practical reasons. The effectiveness of the instruction was to some extent attributed to the consistent efforts of the same science teacher for six years. Despite the evidence that the study provided about the role of instruction in the development of epistemic ideas, the required efforts were laborious and time-consuming. Unfortunately, this context and time-frame (the same teacher for six years) is unrealistic for everyday classroom practice.

The potential for instruction to promote young students' epistemic ideas on a more constraint period of time is indicated by the study of Carey, Evans, Honda, Jay, and Unger (1987) study. Carey et al. (1987) studied the advancement of seventy-six seventh grade (12 years old) students' epistemic conceptions before and after a three-week constructivist unit that replaced a curriculum unit about the scientific method. During the first week of the intervention, instruction was focused on helping students realize the importance of systematic experimentation in collecting evidence to test ideas about phenomena. Activities were such that aimed to help students realize that scientists study phenomena they do not actually observe and that their interpretations of evidence may not be definitely proven 'right' (Carey et al., 1987). During the next two weeks of the intervention students were presented with a problem about what makes bread rise. Students were encouraged to think about the ingredients of bread and the chemical reactions among the ingredients that may cause the rising of the bread. Subsequently, the teacher encouraged the statement of hypotheses that could explain the phenomenon and then students were encouraged to experiment with the ingredients to find supporting evidence. Instruction helped students to structure their investigations and reason about evidence in relation to the hypothesis they examined.

Twenty-seven students were interviewed using a clinical interview before and after instruction. The interview focused on students' ideas about the nature and purpose of science, the main elements of scientific inquiry (ideas, experiment, and evidence) and the relation among these elements. Before instruction the majority of students considered that the purpose of science is to do things and invent new cures, while after instruction students' views were more variable including beliefs about the need to test scientists' ideas. The change in students' ideas regarding the nature of science was small but statistically significant. In terms of the nature of hypotheses, students did not know what a hypothesis was before instruction, while they developed a fairly advanced view that a hypothesis is an idea or a guess that can be explicitly tested with an experiment. In regard to the role of experiments, at the beginning of the study students thought that an experiment is when you try things, while at the end of the study more than half the students considered that experiments test ideas. One of the most robust findings of the study was that before instruction students thought that scientists just do experiments and research, while after instruction they thought that scientists' work is a purposeful activity driven by their ideas. When students were questioned before instruction about when and why scientists change their ideas students could not differentiate ideas from experiments. Moreover, they thought that if scientists got unexpected results they should go back and fix the problem. Another robust finding of the Carey et al. (1987) study was that after instruction students clearly distinguished ideas from experiments and thus they could reason that when scientists get unexpected results they may need to revise their ideas (Carey et al., 1987). The study of Carey et al. (1987) concur with the results of the Smith et al. (2000) study in that students in the late years of elementary school consider the enterprise of science and the work of scientists unproblematically. This means that students hold a mechanistic view of science according to which scientists do research following standard and straightforward procedures. Students' views of science, at the age of 10-12 years old, do not show any understanding of the underlying role of scientists' ideas and the role of experiments as tests of students' ideas. Nevertheless, both studies show evidence that instruction plays a pervasive role in facilitating young students' (12 years old) understanding of science as purposeful activity directed towards developing better understandings of phenomena in the world.

Another study by Conley et al. (2004) provides more evidence that instruction may cause change in elementary school students' conceptions about the nature of knowledge and knowing in science. Within the context of a district-wide hands-on science program Conley et al. (2004) examined change in 187 fifth grade students' personal epistemology over the course of a nine-week inquiry-oriented science unit about the chemical properties of substances. The content of the instruction was constant among the twelve participating classrooms and involved activities that promoted science process skills: performing a science investigation, collecting data, making observations, interpreting results, drawing conclusions and justifying conclusions on the basis of evidence from observations. Instruction was delivered by classroom teachers who received kits with all the materials they needed for their students, along with a teacher's guide that described in detail all the lessons of the unit. It was made explicit to teachers that they should introduce activities to students and let them explore phenomena as well as make their own discoveries using the provided materials. The teacher guide emphasized the need to promote thinking processes and exchange of ideas in class, while it did not provide explicit suggestions about how teachers could help their students draw conclusions from evidence and in turn, use the evidence to construct conceptual understandings (Conley et al., 2004).

Conley et al. (2004) conceptualized personal epistemology along the four dimensions of certainty, simplicity, source and justification and used a 26-item personal epistemology instrument adapted from Elder (2002). The study provided evidence that students' views related to the certainty and source dimensions of personal epistemology appeared more advanced at the completion of the nine-week unit. However, the lack of comparison classrooms in the design of the study does not allow any strong inferences about what caused change in students' epistemic views (Conley et al., 2004).

The results of the three studies presented in this section indicate that when students are encouraged to engage in inquiry-based science learning activities their understanding of the nature of science and scientific activity develops. The duration of the three studies ranged from three weeks to six years. While the Smith et al. (2000) study is important in providing evidence that elementary school students' ideas may become fairly advanced, the long duration of the intervention is unrealistic for everyday classroom practice. However, the Carey et al. (1987) and Conley et al. (2004) studies show that even three-week interventions may also facilitate epistemic understandings. This means that beyond duration of the intervention, the content of the intervention plays a role. Even the Conley et al. (2004) study that used a hands-on curriculum which is different from the inquiry-oriented curriculums followed in the other two studies (hands-on does not emphasize the interpretation of evidence and the development of conceptual understandings) provided evidence of change. However, despite that the Carey et al. (1987) and the Conley et al. (2004) studies showed evidence of change, change was rather modest. This difficulty in changing epistemic beliefs may be analogous to difficulty of change reported in conceptual change research.

Conceptual change research provides ample evidence about the difficulty of change in prior conceptions (Vosniadou, & Brewer, 1992; Vosniadou, 1994; Vosniadou, Ioannides, Demitracopoulou, & Papademetriou, 2001; Chi, Slotta, & de Leeuw, 1994). Researchers conducting research in conceptual change consider that students' initial conceptions of scientific phenomena can be considered naïve, fundamentally different from the scientifically accepted models and largely influenced by everyday experience (Vosniadou, 1994). Conceptual change researchers, similar to researchers supporting the epistemological theories framework in the study of epistemology, consider that students' alternative conceptions are theory-like. The process of adopting new conceptions, namely the conceptual change process, can be a daunting task on the part of the learner requiring many false starts and mistakes and frequent reversals of directions (Posner, Strike, Hewson, & Gertzog, 1982).

Personal epistemology and conceptual structures are seemingly and perhaps similarly resistant to change. The conditions that induce change may thus be analogous. Posner et al. (1982) argued that that there are four necessary conditions for conceptual change to occur: (1) dissatisfaction with existing conceptions, (2) individuals must find new alternatives intelligible and useful, (3) individuals must find the new beliefs initially plausible, and (4) new conceptions should appear fruitful, lead to new insights, discoveries and learning. On the other hand, in a qualitative study on undergraduate students' belief change process, Bendixen (2002) proposed a four-component model of belief change revolving around the concept of epistemic doubt (the doubting of one's beliefs at any stage of epistemological development). Bendixen argued that epistemic doubt was essential for epistemological belief change to take place. One could argue that the concept of epistemic doubt parallels one of the four necessary conditions for conceptual change, the experience of dissatisfaction with existing conceptions. Bendixen also provided evidence that individuals must find new beliefs intelligible and useful. This finding parallels the two other necessary conditions for conceptual change: intelligibility and fruitfulness of new conceptions.

Posner et al. (1982) outlined five features of a conceptual ecology, aspects of one's theoretical frameworks, which may shape the process of conceptual change: (1) the presence of anomalies (something that one cannot understand), (2) the existence of analogies and metaphors that make the new concepts more intelligible, (3) epistemological commitments, (4) metaphysical beliefs and concepts, and (5) other knowledge in other fields and competing concepts. While these aspects are assumed to influence the conceptual change process, their application in the process of belief change may only be hypothesized because there is not empirical evidence to support it. The assumed similarity between the two processes of conceptual change and personal epistemology advancement justifies the use of parallel methods. Traditional research on conceptual change originated primarily within the broader context of science education research. Most of this research was influenced by the five necessary conditions for conceptual change outlined by Posner et al. (1982). The first feature that relates to the state of disequilibrium, creating dissatisfaction with current conceptions of the learner, was particularly influential. Thus, science researchers focused on the process of eliciting and confronting students' alternative conceptions through a variety of approaches. Prediction laboratories, instructional modeling, use of analogies, field trips, hierarchy-refutation/remediation (booklets that alert students to their misconceptions and provide hierarchical treatment to the misconceptions), hands-on manipulations and role-playing are only a few examples (Guzzetti, Snyder, Glass, & Gamas, 1993) of activities employed to facilitate revision of knowledge structures.

Various activities employed in science education require physical activity on students' part. While the nature of the targeted misconception may regulate the level of the required physical activity, it has been argued, that it is not physical activity but mental activity that may lead the way to substantial revision of knowledge structures (Diakidoy, Kendou, & Ioannides, 2003). In the case of conceptual change, mental activity may be facilitated towards the desired direction by creating provoking cognitive conflicts. Nevertheless, Vosniadou et al. (2001) argue that cognitive conflict should be used with care; they argue that maybe is not enough to replace the misconception with the scientific conception and that underlying understandings should be identified and be confronted. Vosniadou et al. (2001) designed a knowledge building learning environment to facilitate fifth grade students' (10-11 years old) conceptual change about force and energy. Instruction was completed within 8 class periods of 90 minutes and was strongly focused on identifying students' prior conceptions and using them for designing activities that helped students revise their initial understandings. Vosniadou et al. (2001) facilitated students' conceptual change through designing experiments to test their own hypotheses, the use of symbols and models to help them develop accurate representations of abstract ideas such as the forces exerted on a constant object as well as the use of group discourse that was used to achieve shared understandings. Assessment of conceptual understandings with pre-post measures indicated that students in the experimental classrooms achieved statistically higher cognitive gains than students in traditional classrooms that followed the standard curriculum. Analysis of in-depth group interviews and classroom discourse indicated that a critical distinction between the two classrooms was that teachers in the experimental classrooms did not provide explanations but encouraged students to develop their own.

Diakidoy and Kendou (2001) used a more short-term instructional intervention to teach fifth grade students (10-11 years old) the earth shape and the day/night cycle. Similar to Vosniadou et al. (2001) a strong emphasis on identifying students' prior conceptions and using demonstrations and models of the earth helped students in the experimental classroom to revise their understandings of the shape of the earth and the day/night cycle substantially more than students in the traditional classroom that followed the standard curriculum. Taken together, the findings of the two studies suggest that elementary school students at the age of 10-11 years old can engage in effective conceptual change. The conditions that induced change can be attributed to the identification of students' prior conceptions and their engagement in activities that confronted their misconceptions and supported the development of their explanations of phenomena through experimentation. Moreover, the Diakidoy and Kendeou (2001) study provided support that conceptual change instruction can be effective even on a more short-term basis.

Interventions to activate productive resources. A basic assumption in this approach is that personal epistemology is not comprised by a small number of large structures but by a large number of small rudimentary epistemological elements (Rosenberg, Hammer, & Phelan, 2006). These elements constitute epistemological resources that are sensitive to context in their activation (Hammer & Elby, 2002). Children have multiple epistemological resources for understanding the various aspects of knowledge (dimensions as these are defined in the epistemological theories approach). For example, in terms of reasoning about the source of knowledge and answering a question like "How do you know X?" children may give many possible answers depending on the context: because someone told them, because X is apparent, because they figured it out from other information, or even because they invented it themselves (Rosenberg et al., 2006). Context is key in the activation of the appropriate epistemological resources. Thus, epistemological advancement is viewed as the activation of appropriate and productive resources depending on each learning situation.

If epistemological resources are successfully activated, then epistemological advancement can be facilitated. What makes a successful activation depends in large measure on designing a context that will naturally elicit students' epistemological resources. Any particular situation may activate various resources simultaneously. Children have multiple epistemological resources and, depending on each situation, these resources may be productive or counterproductive. Children have resources for understanding the general nature of knowledge and how it originates, for understanding epistemological activities (e.g. designing an experiment) and also for understanding epistemological stances. For instance, "knowledge as propagated stuff" and "knowledge as free creation" are both resources about the nature of knowledge. If a child states "I'm afraid we are going to miss our trip tomorrow because it's going to rain" and we ask "How do you know?", then the child may respond "Because I watched the weather forecast" or even "Because I noticed changes in temperature and clouds in the sky". Therefore, children may think in various ways about the nature of knowledge. We just need to 'scaffold' their thinking towards appropriate resources that may facilitate their epistemological advancement.

The success of this approach depends upon alignment between students' productive epistemological resources and the context in which they will be activated. Previous research supports the idea of resource activation. Louca et al. (2004) showed that in a lesson about leaf color change in a third-grade classroom, students had difficulty focusing on how this phenomenon occurs. They tended to provide teleological explanations like "because leaves die", but failed to reason about the mechanisms that cause leaf change. In turn, the teacher who observed these difficulties provided an analogy from everyday reasoning: baking biscuits for a birthday. The answer to the why question (why do you bake biscuits?) is "because I'm having my birthday" and the answer to the how question (how do you bake biscuits?) is a presentation of the recipe and an explanation of the baking process. This analogy from everyday reasoning considerably helped students to focus on the how question. This means that in the particular context an example from everyday life supported students' scientific reasoning. Per Driver et al. (1996) an aspect of scientific reasoning entails the ability to reason about the 'how' of phenomena instead of the 'why' because it entails thinking about processes and explains phenomena.

Similar results from classroom-based interventions were produced with older students as well. Rosenberg et al. (2006) documented evidence of an impressive shift in the 15 minute discussion by a group of eighth graders about the rock cycle. Their assignment was to construct their own models about how three types of rock can be connected in a cycle. At the beginning of the discussion the students were much detracted, reviewing worksheets and notes and using technical vocabulary they did not understand. When the teacher noticed their difficulty in thinking about the science content independently and creatively she proceeded to one simple instructional intervention: She told them: “Start from what you know”. This suggestion instigated a completely different dynamic in the group and soon students started giving their own explanations and understandings about rock formation. The overall quality of the discussion changed and students’ participation was meaningful and original. At the end, students were able to construct their own model of rock formation without copying book or expert information (Rosenberg et al., 2006).

Hammer and Elby (2003) reported on their efforts as instructors at the college level and high school level in teaching introductory physics. Basic objectives of their approach involved the development of an awareness of everyday thinking and use of learning to refine everyday thinking. These objectives reflect Hammer and Elby’s (2003) concern in situating learning physics in the context of everyday life. For instance, in order to teach students the conjectural nature of ideas in science and their interrelatedness they used the example of moving furniture or fitting luggage in a trunk. If one piece of furniture is moved, then the location of all other furniture will also change. Similar analogies may be drawn from the example of fitting luggage in a trunk (e.g. what if the big piece of luggage is put first?) or from story writing (e.g. if I intend to write about Eloise dying in May she cannot be the one who will save Simon in June); (Hammer & Elby, 2003). A third objective of Hammer and Elby’s (2003) approach involves learning principled consistency indicating that their approach does not undermine learning of principled theoretical frameworks (e.g. Newton’s law of motion).

The instructional approaches presented above were designed to help students learn physics within the context of everyday life. Drawing analogies from examples that students consider common sense motivates them to consider how such everyday examples relate to perhaps ‘intimidating’ concepts and processes in science. The key in this approach is to design contexts that can encourage students to use resources that will help them to reason in more scientifically valid and meaningful ways. It should be noted that approaches under the resources framework are neither strictly conceptual nor epistemological. They can be characterized as focused on conceptual understandings with large emphasis on epistemological considerations.

The present study aimed to facilitate epistemological advancement by orchestrating available epistemological resources and context of activation. Before the start of the intervention, students' available epistemological resources were identified and guided the design of an appropriate context. Louca et al. (2004) and Rosenberg et al. (2006) provided initial support for Hammer and Elby's (2002) argument that students are equipped with the building blocks of an advanced epistemology. In contrast with the process of facilitating substitution of prior conceptions with scientific explanations used in conceptual change research, the resources framework supports the view that students' prior conceptions should not be changed nor replaced. They should rather be activated in the right direction to give rise to advanced epistemological thinking. (Hammer & Elby, 2002).

Epistemological resources are derived from everyday life and form the basis of children's reasoning ability in making sense of their everyday encounters with activities that implicitly entail information about the nature and sources of knowledge. In the proposed study students were 'reminded' about their frequent encounters with epistemological activities via the use of analogies. While the use of analogies has been suggested by Hammer and Elby (2002) as a useful instructional medium for activating epistemological resources, this study presented them to students in the form of a text.

Text Interventions and Personal Epistemology Advancement

Epistemological Theories Framework: use of refutation text

The main goal of interventions in conceptual change research is to bring to surface students' alternative conceptions about physical phenomena, acknowledge, refute them and then provide the scientifically valid explanations (Posner et al., 1982). This is the main function of refutation texts as they are used in conceptual change research conducted by reading education researchers. It has been argued that theory-like conceptualizations of personal epistemology, similar to conceptualizations of knowledge structures about natural phenomena, justify the use of methods used in conceptual change research. The refutation text structure is one research medium that has been used to help students change their prior conceptions and learn from text. As such, refutation text influences conceptual change and learning from text.

Refutation text and conceptual change. While the primary function of an expository text is to inform, the primary function of a refutation text is to persuade. A refutation text acknowledges readers' alternative conceptions, refutes them and provides the scientifically accepted ones as more viable and superior (Hynd, 2001). By identifying extant understandings and refuting them a refutation text creates cognitive conflict. This is the main function of a refutation text that renders it appropriate for conceptual change (Dole, 2000).

Refutation text supports conceptual change of students at varying ages: elementary school (Diakidoy, Kendeou, & Ioannides, 2003; Mason, Gava, and Boldrin, 2008), high school (Alvermann, Hynd, & Qian, 1995) and college students (Hynd, Alvermann, & Qian, 1997). In a study designed to facilitate elementary school students' (11-12 years old) conceptual change learning about the concept of energy, students who read the refutation text (as opposed to expository text and traditional instruction) were found to demonstrate the larger learning gains in immediate and delayed assessments with respect to their understandings of the concept of energy (Diakidoy, Kendou, & Ioannides, 2003). This result provided indirect evidence that students who had read the refutation text engaged in more conceptual change processes that resulted in their superior performance on the immediate and delayed post-test (Diakidoy, Kendeou, & Ioannides, 2003). Another study that lends further support of the facilitative effects of refutation text to conceptual change processes of elementary school students was conducted by Mason, Gava, and Boldrin (2008). Their study examined the effect of refutation text on fifth grade students' conceptual change about light and provided evidence that when compared with standard expository text, refutation was superior in creating cognitive conflict and leading to more pervasive knowledge restructuring.

Refutation text and learning from text. Learning from text depends on the construction of a coherent mental representation of the text and its integration with relevant prior knowledge (McNamara, Kintch, Songer, & Kintch, 1996). Coherence of the mental representation depends on the level of related prior knowledge as well as on inference generation to provide missing connections or implicit connections among pieces of text (bridging inferences). Elaborative inferences on the other hand contribute to a more complete mental representation of the text that incorporates readers' relevant background knowledge (Diakidoy, Mouskounti, & Ioannides, 2011). Inconsistent prior knowledge however, may cause invalid inference generation leading to incomplete or inaccurate mental representation.

Refutation text seems to support conceptual change and learning from text of students with inconsistent prior knowledge. Previous research provides evidence that refutation text enhances online conceptual change processes but does not seem to support memory for text (Kendeou & van de Broek, 2007). Rather, facilitative refutation effects are more pronounced on tasks that require elaborative inferences (e.g. Mason, Gava, & Boldrin, 2008) and thus meaningful learning from text. A recent study by Diakidoy, Mouskounti, and Ioannides (2011) examined the particular effect of refutation text on the amount of information recalled from text, as well as on the number and type of generated inferences. Sixty-one undergraduate students were assigned in two groups. Group 1 read an expository text about energy, while group 2 read a refutation text about energy. Comprehension of text was examined with a recall measure while learning from text was measured with a delayed post test that examined students' understandings about energy. Students' recall protocols were scored for amount of text recalled, number of valid inferences as well as type of inferences (bridging or elaborative). The results of the study indicated that students who read the refutation text provided more global and elaborative inferences and they also achieved higher learning gains on the delayed test about energy. Effects were more pronounced for readers with low prior knowledge (Diakidoy, Mouskounti, & Ioannides, 2011). It seems thus, that refutation text enhances learning from text by facilitating the construction of coherent and accurate mental representations of the text resulting from the generation of global and elaborative inferences. While the level (high or low) and quality (accurate or inaccurate) of prior knowledge influences the level of coherence of the mental representation (Cote, Goldman, & Saul, 1998) the refutation text seems to compensate for problems related to low or inaccurate prior knowledge. Thus, the facilitative effect of the refutation text is more pronounced for readers with low or inaccurate prior knowledge.

Refutation text and epistemological advancement. Within the context of epistemological belief change there are a few experimental studies that examine the effectiveness of refutation texts with adult participants providing initial evidence of the influence of text-based interventions in the advancement of personal epistemology. Mason and Boscolo (2004) showed that a dual position text (a text that presents two different approaches to the same topic) helped undergraduate students to change their topic-specific beliefs on genetically modified food. Importantly, change was evident only in students with a more sophisticated personal epistemology. Gill, Ashton, and Algina (2004) employed the technique of augmented activation (signaling that alerts students that they are about to read information that may conflict with their existing views) along with the use of refutation text to challenge math education college students' domain general and domain specific epistemic beliefs in teaching and learning mathematics. The treatment group that received this instructional intervention demonstrated greater change in both domain general and domain specific epistemic beliefs compared to the students who read an expository text on constructivist teaching practices in mathematics. However, it is unclear what caused this belief change, the refutation text, the augmented activation or both. Despite the fact that the intervention produced change in both domain general and domain specific beliefs change was rather small as indicated by the modest effect sizes.

More to the focus of this study, Kienhues, Bromme, and Stahl (2009) attempted to influence fifty-eight university students' domain specific epistemic beliefs using a refutation text with epistemological considerations. They gave one group a text about DNA fingerprinting that began by introducing the naive notion that DNA fingerprinting is a safe method. It then went on to refute this notion by focusing on the uncertainties and difficulties of DNA fingerprinting. The second group read a text that focused on facts about the method of fingerprinting without any mention of controversies and uncertainties. The impact of this intervention was not made clear because the results differed according to the two different measures using in the study to assess domain specific epistemic beliefs. The results showed that the interventional text did not benefit students with non-availing beliefs, whereas students who were considered to have availing beliefs at the beginning of the study, embraced less availing beliefs after the intervention. Moreover, students with availing and non-availing beliefs who read the informational text seemed to have less availing beliefs at the end of the study. Results according to a second measure that assessed domain specific epistemic beliefs confirmed researchers' expectations about a shift of the group with less availing beliefs towards more availing beliefs and a lack of change in the group of students with availing beliefs. Again, students with availing beliefs who had read the informational text seemed to have less availing beliefs at the end of the study. The pattern of results according to the second measure was in the expected direction: beliefs were revised when they were at odds with instruction.

Overall, the studies presented above show that change is plausible through the refutation text structure, although the pattern of change is confusing. Different instruments seem to yield different results while effect sizes and statistical power are generally low. Therefore the outcomes of these studies are to be interpreted with caution. In addition, one could argue that beyond measurement problems there is also a lack of alignment between instruments used to evaluate change and the main topic of the texts. In two of the three studies reported above (Gill et al., 2004; Kienhues, Bromme, & Stahl, 2009) the refutation texts that were used implied epistemological issues through the discussion of topics where knowledge is considered to be tentative and complex (e.g. DNA fingerprinting). Given that there were problems in capturing change it seems that the themes and issues to be discussed in the refutation text should be aligned with the structure and the items of the instrument used to assess change in epistemology. Thus, in the context of the present study, the refutation text that was used discussed exact issues of epistemology in science per se.

The difficulty of change via the use of refutation text however, could be a function of the conceptualization of beliefs. There is uncertainty in the area of epistemic beliefs about their structure and if this is not taken into consideration when designing interventions to impact beliefs there could be a mismatch between what is the target of change and the methods used to cause this change. To examine this issue of structure in this study two different approaches that regard personal epistemology in fundamentally different ways were compared.

Muis (2008) argued that instructional interventions should perhaps focus on teaching directly about epistemology, making salient unarticulated conceptions. Studies reviewed so far have used refutation texts to imply the problematic nature of knowledge development in science. Taking a step further, the present study used a refutation text that directly discussed core epistemological issues about the tentative, evolving and complex nature of scientific knowledge. It also discussed the importance of a scientist's ideas and the justification of knowledge through back and forth research procedures.

It should be noted however, that although refutation text has been used with relative success with elementary school students in conceptual change research, there is not empirical evidence supporting its use with elementary school students in personal epistemology advancement. Nevertheless, according to the epistemological theories framework, it was hypothesized that because of common ground between the process of conceptual change and epistemological advancement the refutation text could be effective in facilitating sixth grade students' personal epistemology advancement.

Epistemological resources framework: successful resource activation

The main purpose of the epistemological resources framework is successful resource activation. Prior research indicated that epistemological resource activation related to simple teacher interventions that guided students' thinking towards productive resources (Hammer & Elby, 2003; Louca et al., 2004; Rosenberg et al., 2006). A basic premise in this approach is that students have productive resources from their everyday reasoning for thinking about knowledge. Epistemological resources are common sense examples from everyday life that serve as p-primes or building blocks for thinking about broader themes and issues. Hammer and Elby (2002; 2003) contend that such examples can be used as epistemological 'bridging' or 'achoring'.

Clement, Brown, and Zietsman (1989) define an anchoring conception as an example from physics that students can understand with confidence and can be used to teach students more difficult ideas especially when the students' preconception makes sense (as opposed to scientific explanations, e.g. the example of the table exerting an upward force on a book). Clement, Brown, and Zietsman indicate that anchoring conceptions should be identified on the basis of their use by students. In their study, anchoring conceptions were identified after students answered correctly multiple choice questions using the particular anchors and expressed high confidence in their answers. The use of anchoring conceptions may be similar to analogical learning.

Analogical learning involves a process of mapping between a source and a target domain (Caplan & Schooler, 1999), akin to the concepts of epistemic forms (a targeted concept) and epistemic games (strategies to construct the knowledge that epistemic forms require) suggested by Collins and Ferguson (1993). Prior research in analogical learning in conjunction with learning from text has examined the level of similarity between the source and target concepts (superficial vs. structural similarities) (Blanchette & Dunbar, 2000), the level of complexity required to process the analogy, as well as construction of analogies within and between domains (Caplan & Schooler, 1999). Alexander, White, Haensly, and Crimmins-Jeanes, (1987) trained fourth grade students on verbal analogy problems of the form A:B:C:? as well as on using inferential comprehension processes. Students were instructed to use text-based ideas, concepts and processes to infer related ideas, concepts and processes from their background knowledge and thus extend their mental representation of the texts, a process that could enhance meaningful learning of the information presented in the text. The results of the Alexander et al. (1987) study indicated that the experimental group students who were trained in analogical learning solved verbal analogy problems significantly better than their peers in the nonexperimental group that had followed the standard instruction. However, instruction did not influence students' inferential comprehension (Alexander et al., 1987). Despite the lack of effect of training on students' ability to generate inferences in far transfer measures, the study of Alexander et al. (1987) pointed to the potential of analogical learning in facilitating inferential comprehension processes.

Within the context of the present study students were not required to generate analogies but to consider analogies presented in the text. Students were guided through the text to examine how common sense examples could be used to reason about aspects of epistemology. Using Collins & Ferguson's (1993) terminology the four dimensions of certainty, simplicity, source and justification represented epistemic forms, while the everyday analogies represented epistemic games.

Text Comprehension

Aspects of personal epistemology impact aspects of comprehension and learning from text. Belief in certain knowledge (a dimension more reliably replicated across studies, DeBacker et al., 2008) impacts conclusions derived from expository text (Schommer, 1990; Kardash & Scholes, 1996), while belief in simple knowledge impacts learning from text (Schommer et al., 1992; Rukavina & Daneman, 1996). Personal epistemology has been also found to relate to comprehension monitoring (Ryan, 1984), self-reported text comprehension strategy use (Dahl et al., 2005) and to conceptual change processes taking place during reading (Kendeou et al., 2011). Thus, personal epistemology influences comprehension processes, strategies and outcomes.

Distinguishing levels of comprehension is an unequivocal practice in reading comprehension research. Remembering a text lies upon preliminary comprehension processes, while learning from text requires deep understanding and ability to apply information derived from text in novel situations (Kintsch, 1994). A textbase refers to encoding of words, phrases and the linguistic relations between them. In other words, it reflects meaning relations among elements within a sentence and across sentences. The resulting representation closely depicts the gist of the information presented in the text. As such, a textbase supports memory for a text (episodic memory). The construction of a situation model on the other hand, requires activation of relevant background knowledge and its integration with the information presented in the text (Kintsch, 1988; 1994). The resulting representation is a broader, more complex and elaborated structure compared to the representation of a textbase (Kintsch, 1994). Thus, the process of constructing a situation model relates or corresponds to learning from text, as activation of prior knowledge and its integration with new text information, creates the necessary conditions for deep learning and storing of knowledge in long-term memory (Kintsch, 2005).

The quality of learning that takes place however, depends on the quality of the textbase as well as prior knowledge (Cote, Goldman, & Saul, 1998). The quality of a textbase refers to the level of coherence established among nearby or distant parts of the text via inference generation processes (bridging). Elaborative inferences on the other hand support the construction of a more elaborated mental representation (situation model) that includes information supplied by the reader such as explanations, predictions and elaborations (Diakidoy et al., 2011). While bridging inferences seem to contribute to the level of coherence of the textbase and thus to memory for text, elaborative inferences support the coherence of the situation model. Consequently, elaborative inferences contribute substantially to learning from text. Coherence of representations also depends on prior knowledge.

Cote, Goldman, and Saul (1998) conceptualized the interactions between quality of textbase and level of prior knowledge in a four-component multidimensional space. According to the proposed model, high knowledge and high quality textbase contribute to the construction of coherent and integrated mental representations (situation model). High knowledge and low quality textbase though, result in assimilated representations (top-down process that may distort text information to conform to prior knowledge). Furthermore, while low prior knowledge and high quality textbase support the construction of coherent albeit encapsulated representations, low prior knowledge and poor quality textbase lead to fragmentary and incoherent representations (Cote et al., 1998). It should be noted that while this multidimensional model provides for level of prior knowledge it may also support hypotheses about the quality of prior knowledge. The quadrant describing assimilated representations resulting from high knowledge use but poor quality textbase may also apply in the case of inaccurate prior knowledge, which has been found to affect on-line comprehension processes and memory for text (Kendeou & van den Broek, 2005).

Level of prior knowledge (Cote, Goldman, & Saul, 1998), quality of prior knowledge (Kendeou & van den Broek, 2005) and inference generation (particularly elaborative inferences) (Diakidoy et al., 2011) seem to support learning from text. In the present study learning from text is critically situated in the center of predicted interactions that were expected to take place in order to influence personal epistemology advancement. As a result, level of prior knowledge in science as well as level of topic knowledge (students' personal epistemology before the beginning of the study) were both examined. Moreover, comprehension measures taken after reading reflected the type of inferences generated as index of the level of processing that occured during reading.

Conceptual change processes take place during reading but may not surface at the memory level (Kendeou et al., 2011). However, this does not preclude learning at a deeper level (Kintch, 1994). Furthermore, belief revision may require activation of prior knowledge and integration with new information derived from text and thus revision processes may surface at the situation model level. Nevertheless, prior conceptions are resistant to change and may take long and sustained efforts before conceptual change processes result in knowledge restructuring (e.g. Vosniadou, 1992). These findings necessitated the use of comprehension measures that would tap both the textbase and the situation model in order to more completely characterize the quality of learning that took place during reading.

Kintch (2005) argued that in designing comprehension questions we should consider the level of processing required to answer them. To demonstrate learning at the situation model level, sensitive measures are needed. Besides sensitive, measures should also be appropriate. McNamara, Kintch, Songer, and Kintch (1996) examined the effects of text cohesion on middle school students' learning from text and found that despite the use of a variety of measures that tapped different levels of representation, effects were not evident. The researchers reasoned that they might not had asked the right questions and this was subsequently supported by their success in revealing effects at a more sensitive task (sorting task).

In this study comprehension lied at the center of all hypothesized interactions. Consequently, type and quality of comprehension measures were fundamentally important. To examine learning at both levels of representation (text base and situation model) a spectrum of measures was needed. Rukavina and Daneman (1996) argued that the success of any intervention may depend on the measures used to assess learning. In effect, they used a variety of measures tapping memory and learning from text. Multiple choice questions and short-essay questions elicited information regarding both the textbase (bridging inferences) and the situation model (elaborative inferences) and were used to uncover the effects of an integrated text format on students' learning from text about the dynamic and evolving nature of scientific knowledge.

Why should learning from text predict epistemology advancement? It was reasoned that if deep learning from text that requires activation of relevant background knowledge and storing in long-term memory takes place, it would result in epistemological advancement. Despite that epistemology measures tapped explicit and implicit views about the nature of knowledge and knowing in science, it was considered that those measures could be not as sensitive to capture students' efforts to revise their conceptions. Consequently, comprehension measures needed to be carefully designed to uncover the exact levels of representation influenced by reading the text.

Prior Knowledge

One of the most robust findings in educational psychology research is that more knowledgeable learners, in general, understand and remember more than their less knowledgeable counterparts (Alexander & Judy, 1988). As a result, it is seen almost as common practice to include prior knowledge as an independent variable in research designs. In this study in particular, examining prior knowledge was critical mainly because the designed interventions were text-based and their success lied in large measure upon comprehending the reading material and learning from it.

A variety of terms is used to denote the construct of prior knowledge in the literature: permanent stored knowledge, prior knowledge state in the knowledge base, background knowledge, personal knowledge (Dochy, Segers, & Buehl, 1999) to name only a few. Nevertheless, operationally defining prior knowledge with clarity and accuracy is usually not considered as important from researchers in the area, mainly because prior knowledge is regarded as a widely understood term. However, the assumed definitions attributed to the construct vary across studies. Despite the use of same or similar terms, definitions assumed under different constructs may also concur (Alexander, 1992). Definitions of prior knowledge impact prior knowledge assessment (Dochy et al., 1999) and as a result they need to be explicitly articulated (Alexander & Judy, 1988).

Alexander, Jetton, and Kulikowich (1995) use the term 'subject-matter knowledge' as an overarching structure that distinguishes between two forms of prior knowledge: domain knowledge and topic knowledge. Domain knowledge constitutes knowledge about a particular field of study and as such it encompasses declarative (knowing that), procedural (knowing how) and conditional (knowing when and where) knowledge and operates at explicit or implicit levels (Alexander & Judy, 1998). While domain knowledge is about breadth (how much one knows in a domain), topic knowledge is about depth and it represents how much a person knows about particular topics in the domain (Alexander, 2003).

In seeking to examine the effects of prior knowledge to learning in general, it is important to consider interactions of prior knowledge with other individual learning variables. Alexander et al. (1998) proposed the Model of Domain Learning (MDL) to present interactions among prior knowledge, interest and text recall. They empirically tested the model with graduate students who were considered to be competent readers capable of processing demanding scientific text and who were engaged in educational studies intending to advance articulated career goals. The model was further supported and verified with undergraduate students whose career aspirations were not that clearly articulated and whose reading skills were not as advanced as graduate students'. Students completed knowledge measures (prior and topic knowledge), a personal interest measure, read texts on human immunology/biology, rated their interest in the texts and proceeded to recall of key text-based ideas. Cluster analysis showed that there were clearly emerging clusters. On the main, cluster 1, included high knowledge students, who recalled more ideas from the text and were highly interested in reading the text. Cluster 3 was composed of the least knowledgeable and least interested students, who recalled the least from the text. Profiles of students in these two clusters seemed to support the MDL. However, data from students falling between these two clusters did not fit the expectations of the model well. For instance, some students were highly interested in reading the texts, comprehended the text well but yet their prior knowledge was not particularly high. Even if interrelationships between prior knowledge, interest and text base comprehension are obscured for that middle ground of students, the MDL is useful at least in providing evidence that there are important interactions between these three variables that need to be taken into account. This study considers all three interacting variables of MDL.

In line with Alexander (2003) this study was concerned with two types of prior knowledge, domain and topic knowledge. Domain knowledge was defined as students' knowledge of fifth grade science content. Fifth grade science content covers topics like properties of matter, dilution, electrical circuits, adaptation and functions of plants and animals, photosynthesis, ecology (e.g. benefits of recycling), human digestive system and how eyes work. This content is more or less the most important amongst content of fourth to sixth grade content (science is taught from grade 4 to grade 6), partly because it is a basic extension of some preliminary concepts taught at fourth grade and also because most of it is considered basic knowledge for learning sixth grade content. Topics like properties of matter contribute to qualifying knowledge of this content as domain knowledge, mainly because they could be considered precursors of learning more fundamental concepts in science (Alexander et al., 1995), like molecules and their state under different temperatures.

Topic knowledge concerns knowledge related to particular learning tasks. This study was concerned with learning from texts that directly discussed particular aspects of epistemology in science. Consequently, topic knowledge needed to be about epistemology in science and the depth of this knowledge (Alexander, 2003) needed also to be assessed. Therefore students' personal epistemology in science assessed at the beginning of the study was defined as students' topic knowledge.

The effects of prior knowledge on performance are usually facilitative, unless it is imprecise (misconceptions). In their review of the literature on prior knowledge and assessment of prior knowledge, Dochy et al. (1999) concluded that it is perhaps better not to have any knowledge instead of having imprecise or wrong knowledge, because the effects are detrimental. However, characterizations of this kind of imprecise knowledge rest upon researchers' theoretical commitments. Conceptual change researchers, in line with the 'epistemological theories framework' (see previous section) underline the need to identify misconceptions and proceed with challenging, refuting, and subsequently replacing them with the scientifically accepted conceptions (Posner et al., 1982). On the other hand, researchers supporting the epistemological resources framework critique this approach as being in contrast with constructivist approaches mainly because instead of identifying prior knowledge and building from it, conceptual change researchers dismiss these alternative conceptions altogether (Hammer & Elby, 2002). In the present study, students' personal epistemology, as it will be measured at the beginning of the study will be considered topic knowledge and will be analyzed as a covariate interacting with other variables to impact text comprehension and learning from text.

Interest

Interest is a multifaceted unique motivational construct that determines the quality and intimacy of a person's interactions with objects, events and ideas (Hidi, 2006). In general, interest has been found to influence attention, goals and learning (Hidi & Renninger, 2006). Two different types of interest have been postulated to explain how a person decides to engage in an activity and under what circumstances the person may revisit the same activity and extend the level of engaging in it. The former refers to situational interest while the latter to individual interest. A third type of interest, topic interest, represents the level of interest when a particular topic is presented and seems to reflect both situational and individual aspects (Ainley, Hidi, & Berndorff, 2002).

Individual interest

Individual interest is a relatively enduring predisposition to attend to certain objects and events and engage in particular activities (Krapp, 1992; Renninger, 1992). Interested activity entails a psychological state of positive affect and persistence and results in increased learning (Ainley, Hidi, & Berndorff, 2002). It is considered more of a trait-like characteristic of the person as opposed to enjoyment that a person may experience from engaging in particular activities (Michael, 2004). Individuals may have various individual interests, some related to the goals of classroom instruction and some not.

Interested individuals sustain in engaged activity even in the face of challenges. Individual interest has been found to have a positive impact on attention, recognition and recall (Renninger & Wozniak, 1985), persistence and effort (Renninger & Hidi, 2002), academic motivation and levels of learning (Schiefele & Krapp, 1996). The effect of individual interest on cognitive performance is more robust when combined with situational interest.

Situational Interest

Situational interest is the psychological state of interest that is generated by specific environmental stimuli (Ainley, Hidi, & Berndorff, 2002) and refers to focused attention and affective reactions (Hidi &Renninger, 2006). Unlike the trait-like nature of individual interest, situational interest emerges from interactions with particular tasks and activities and as such it is context-bound. Consequently, it may or may not be maintained (Ainley, Hidi, & Berndorff, 2002).

Particular texts may trigger such reactions. Wade, Buxton and Kelly (1999) examined the influence of text-interest, tantamount to situational interest, to the recall of expository text. Two groups of undergraduate students read two different types of texts about dinosaurs. The first was an encyclopedia entry, while the other was a Newsweek article. Students completed measures of prior knowledge and individual interest in the topic of dinosaurs and they stopped during reading (at whatever point they wished to) to refer to their reactions to the text. Retrospectively, after reading they were asked to state what made the text interesting and what uninteresting. Results indicated that a text characteristic that seemed to trigger interest was importance, value and novelty of ideas presented in the text, unexpected information, connections that could be drawn between readers' prior knowledge and text information, imagery and descriptive language as well as connections drawn by the author (e.g. examples and analogies). Lack of cohesion, difficult vocabulary, inadequate explanation and background information were characteristics that made the texts uninteresting. In a second experiment importance was highly related to interest and their interaction predicted significantly text recall. The results of Wade, Buxton and Kelly's research are particularly informative for the text-based interventions of the current study. Both types of the texts that were used in the present study were expected to encourage connections with students' ideas and conceptions as they were rich in examples and explanations.

Situational interest positively influences reading comprehension (Alexander & Jetton, 1996), attention and inferencing (McDaniel, Waddill, Finstad, & Bourg, 2000), integration of information with prior knowledge (Kintsch, 1980), and enhances learning (Schraw, Bruning, & Svoboda, 1995). Designing learning materials, tasks and environments that may trigger situational interest are particularly effective strategies in motivating the 'academically unmotivated' or students with minimal prior knowledge or interest in a particular topic (Hidi & Harackiewicz, 2000). Triggering situational interest is a useful practice to motivate the 'academically unmotivated' especially when contradicting research rejects the use of rewards and incentives (a widely known practice among educators) irrespective of the context of their use (see Michael, Hickey, & Zuiker, 2005). Environmental stimuli trigger situational interest that in turn and through subsequent stages, a maintained individual interest may develop into an emerging and subsequently well-developed individual interest (Hidi & Renninger, 2006).

These two types of interest were a central part of the design of this research. As it has been previously discussed, text comprehension was considered pivotal in influencing personal epistemology advancement. It was expected that understanding and relating the main ideas of the texts would help the students revise and advance their ideas about the nature of knowledge and knowing in science. Research that specifically examined the effects of interest on recall and text comprehension underlined the role of interest in learning from text (Hidi, 2001). A study by Schraw et al. (1995) provided support of the enhancing role of situational interest in text recall and Schiefele (1998) and Schiefele and Krapp (1996) provided evidence of the role of interest in recall, deep comprehension, organization of knowledge structures and learning. In essence then, interest (situational or individual) was expected to impact text comprehension both at the textbase level (as reflected by the impact on recall) and on the situation model level (as reflected by the impact on measures that assessed learning from text).

The Present Study

This research was primarily concerned with advancing sixth grade students' personal epistemology in science examining whether epistemological advancement could be facilitated by means of short-term interventions in the late years of elementary school. In particular, the first research question of the study was concerned with the comparison of two text-based interventions in terms of their effectiveness in facilitating sixth grade students' personal epistemology advancement in science. The two text-based instructional interventions were designed and developed upon the antithetical assumptions of two theoretical frameworks: the *epistemological theories* framework (Hofer & Pintrich, 1997) and the *epistemological resources* framework (Hammer & Elby, 2002). The epistemological theories framework assumes consistency and coherence in personal epistemology (e.g. Hofer & Pintrich, 1997), while the epistemological resources framework assumes a fragmented structure largely influenced by context (e.g. Hammer & Elby, 2002). The two proposed interventions were text-based and designed upon the assumptions of the two frameworks in terms of coherence. The assumed coherence of personal epistemology according to the epistemological theories framework justified the use of refutation text that identified, refuted extant understandings and provided more satisfactory alternatives (Hynd, 2001; Dole, 2000). In accordance with the epistemological resources framework, an analogy text, which featured analogies between aspects of personal epistemology and examples from everyday life (Clement et al., 1989; Collins & Ferguson, 1993) was used. It was expected that the effectiveness of the two interventions would be dependent upon the underlying structure of personal epistemology. In particular, it was anticipated that if the underlying structure of personal epistemology seemed to be multidimensional, then the epistemological theories intervention (refutation text) would be more effective. On the other hand, it was expected that evidence of a fragmented structure would favor the epistemological resources intervention (analogy text). The comparison of the expected effectiveness of the two interventions was anticipated to inform classroom practice in regard to feasible instructional approaches that could be undertaken to facilitate elementary school students' personal epistemology advancement. Furthermore, it was reasoned that the comparison of the two approaches would provide insights about the structure of personal epistemology.

A second aspect of the first research question was concerned with the examination of the role of text comprehension, interest and prior knowledge on the process of epistemological advancement. Text comprehension was a critical variable in this study because it was anticipated to be at the center of expected interactions between prior knowledge, interest and personal epistemology advancement. Students' memory for text and learning from text (Kintsch, 1994) was assessed in order to specifically identify intervention effects. In particular it was assumed, that interest and prior knowledge would influence personal epistemology advancement only via their interactions with text comprehension.

On the basis of this assumption the second research question was particularly concerned with uncovering the impact of interest, prior knowledge and their possible interactions with text type on the comprehension of the interventional texts. As it has already been discussed text comprehension was considered the medium of personal epistemology advancement and therefore it was considered important to understand the variables that influenced it. More interested and more knowledgeable students were expected to learn more from reading the texts. Moreover, the level of students' personal epistemology at the beginning of the study was also assumed to have an impact on text comprehension. At the same time however, text type was anticipated to interact with interest and prior knowledge and subsequently influence text comprehension.

Two types of interest were examined: personal and situation interest (Ainley, Hidi, & Berndorff, 2002). Personal interest in science was measured with a short questionnaire tapping students interest in the domain of science (compared to four other domains), while situation interest was measured with a short question that appeared to students at the completion of reading. The question required students to report the extent to which they found the particular text interesting. Moreover, two types of prior knowledge were examined: domain and topic (Alexander, 2003). Domain knowledge was measured with a test that examined students' knowledge of fifth grade science content, while personal epistemology as measured at the beginning of the study was considered topic knowledge.

Research that associates prior knowledge and interest to comprehension provides support of the interrelationships of these three variables as depicted by the Model of Domain Learning (Alexander, 2003). The model would predict that more knowledgeable and interested students will gain more from reading the text. However, despite that previous research provides mixed results about the impact of refutation text on revising epistemic views, results indicate overall that alternative text structures like the refutation structure may benefit students with less availing (appropriate) epistemic views (e.g. Kienhues, 2008). This relationship however, could be mediated by reported individual and situational interests because interested individuals are expected to more meaningfully engage and sustain in reading the texts (Hidi, 2006). The intervention texts that represented the two theoretical frameworks were both rich in examples and explanations that according to previous research represent characteristics that are expected to trigger interest and increase recall (Wade, Buxton & Kelly, 1999). On the other hand, less knowledgeable and students with less availing views may be find the texts difficult to process and therefore may refrain from comprehending them.

As previously discussed in the presentation of research questions and related hypotheses at the end of Chapter 1, directional hypotheses are not appropriate in this study because of its focus on comparing two instructional interventions derived from different frameworks. Therefore in response to research questions 1 and 2, it was expected that the interplay of text type, prior knowledge (domain and topic) and interest (individual and situational) would exert an impact on text comprehension that would subsequently influence personal epistemology advancement.

Personal epistemology represented the main dependent variable of the study and therefore its reliable and valid measurement was critical. The third research question was concerned with this exact aspect of measurement of personal epistemology. It specifically and examined the extent to which a newly developed domain specific personal epistemology instrument would reliably measure sixth grade students' personal epistemology in science. Attending to concerns about measurement shortcomings of existing instruments (DeBacker et al., 2008) this study examined the assessment of personal epistemology via the use of a science-specific questionnaire appropriate for sixth-grade students (11-12 years old) with respect to format and language. In this instrument beliefs about the nature of knowledge (certainty, simplicity) and the nature of knowing (source and justification) in science were examined, making fine but important distinctions between: (a) epistemic and learning beliefs

(Sandoval, 2009; Elby, 2009), and (b) students' conceptions about the work of scientists and students' conceptions about their own learning approaches in science (Muis, Bendixen, & Haerle, 2006). Attention to such distinctions as well as attention to domain specificity at the item level was expected to result into a reliable personal epistemology instrument.

The instrument consisted of two parts. The first part examined personal epistemology explicitly and the second part examined personal epistemology implicitly. The third research question was also concerned with comparing these two different types of assessment of personal epistemology in terms of the extent to which they were appropriate for upper elementary school students. It was reasoned that both types of personal epistemology assessment would be comparable in terms of their reliability and validity in examining sixth grade students' personal epistemology in science because they were both developed on the basis of the same underlying principles of domain specificity, emphasis on student's views about scientists' work as well as emphasis on views about knowledge and knowing and not about learning.

The third research question aimed also to examine the manifestation of the hypothesized four-dimensional structure in the epistemology of sixth grade students in the domain of science. It was expected that an emergence of four interrelated dimensions would provide support for the epistemological theories framework, while the lack of clearly emerging factors would strengthen the epistemological resources framework.

CHAPTER 3

Method

Pilot Study

Three new instruments were developed for the assessment of the main variables of the study: a Personal Epistemology in Science Questionnaire, a Personal Interest in Science Questionnaire and a Prior Knowledge in Science test. A small-scale pilot study followed by a main pilot study were undertaken to establish the reliability of the three instruments. The small-scale pilot study (N=57) revealed serious reliability problems with the instruments developed to assess personal epistemology and prior knowledge. It was successful however in establishing reliability for the personal interest questionnaire. Major revisions were subsequently made in the personal epistemology and prior knowledge measures and a second pilot study was conducted to establish their reliability. A detailed description of the main pilot study follows.

Rationale of Personal Epistemology in Science Questionnaire (PESQ) development

Three major issues with current personal epistemology instruments were identified in Chapter 2: lack of domain specificity at the item level (domain should not just be stated; rather, items should address issues idiosyncratically tied to the domain of interest); lack of distinction between views about knowledge from views about learning (it is suggested that these two viewpoints are disparate enough to merge within the same instrument); and lack of distinction between students' views about their own efforts in science from scientists' work in science. This distinction should be made within views about knowledge. Consider for instance, the following item from Stathopoulou and Vosniadou's (2007) GEBEP instrument: 'Most of physics problems can be solved easily when you have read the step by step methodology you need to follow'. It requires students to reflect on their own strategies in learning physics. It belongs however in the same subscale with the following item: 'Scientists invent new knowledge by carefully following prescribed research procedures') that require students to reflect on their beliefs about scientists' practices. It is reasoned that such variability in the referential point of items appearing in the same instrument and under the same subscale may pose reliability and validity problems. Items similar to the first example may measure practical epistemologies (students' views about their own efforts in learning science), while items such as the second example may measure formal epistemology (students' views about scientists' practices) (Sandoval, 2005; Hogan, 2000). However, 11-12 years old students in

Cyprus have very limited experiences in developing their own hypotheses and in designing their own experiments to test their hypotheses. Despite the fact that the science curriculum is based on a constructivist philosophy, instruction is overall teacher-centered. Students conduct experiments based on questions, hypotheses and materials provided by the teacher. Thus, it was decided not to include students' views about their own learning in science in this instrument. It should be noted that this distinction applies to a larger extent to the nature of knowing in science (as opposed to the nature of knowledge) and particularly to the dimension 'source' (this dimension reveals information about where knowledge resides and how one goes about searching for it). It is important thus to distinguish between students' and scientists' efforts in searching and justifying knowledge.

Structure and Content of the Personal Epistemology in Science Questionnaire (PESQ)

Motivated by the work of Hofer and Pintrich (1997) and Stathopoulou and Vosniadou (2007) the dimensions certainty, simplicity, source and justification were chosen to express the core epistemic views of sixth grade students in science. Moreover, the manifestation of these dimensions in the domain of science was motivated by the work of Driver et al. (1996) and Carey and Smith (1987) whose research on students' views of science provide rich qualitative and quantitative data that generate insights about how students at the age of 9-16 talk and think about the enterprise of science, the aspects of it they may understand and the aspects they may find challenging. For instance, Driver et al. (1996) provided evidence that students at the age of 9-12 years old consider that the goal of science is to describe phenomena and not to explain phenomena. It was thus assumed that if students cannot reason about the explanation processes of the scientific enterprise then this difficulty may hinder their understanding of the tentativeness of scientific knowledge (explanations of underlying mechanisms may be considered more tentative than descriptions of observable characteristics of phenomena). Consequently, they might not be able to reason about the uncertainty of knowledge in science.

Similar to Stathopoulou and Vosniadou (2007) it was hypothesized that the core dimensions were complex and multifaceted and thus each dimension was further conceptualized in a number of subscales. Six subscales were adapted from the GEBEP and others were developed based on the Driver et al. (1996) study. Despite that the underlying theme of six subscales was used, only 14 items in total (13 statements and one scenario) were adapted from the GEBEP. Three items were adapted from Elder's (2002) instrument (2002) and one scenario was inspired by the Hammer and Elby's (2003) EBAP instrument. The rest 71 items and 18 scenarios were newly developed.

GEBEP concerns students' views about physics, while the present instrument concerns science. Language was kept simpler to be appropriate for sixth graders. Moreover, specific examples were used in a number of items to make them less abstract and easier for younger students. Examples were used not only to make the items easier to answer, but also to make the items domain specific. Certain items that refer to scientists and the work they do, could as well apply to other fields of science. Thus, a second reason examples were used, was to keep students in the mindset of science. There are two parts in this instrument and all the items in both parts fall under one of the four dimensions expressed in ten subscales. The instrument consisted of 88 items in Part A and 21 items in Part B. In Part B there were two scenarios for each subscale. The only exception was the subscale titled: 'knowledge is certain and unchanging vs. tentative and evolving' under the dimension of certainty that consisted of three scenarios.

Certainty. Three subscales were chosen to reflect this dimension (28 statements and seven scenarios): The purpose of science is to provide explanations vs. provide a picture of the world (six statements - three with a positive and three with a negative valence - / two scenarios); knowledge is certain and unchanging vs. tentative and evolving (15 statements - nine with a positive valence and six with negative - / three scenarios); and knowledge in science is conceptualized as absolute truth vs. as interpretation attempts (seven statements - three with positive and four with negative valence - / two scenarios). Subscale 1 was motivated by the Driver et al. (1996) study. Students' views about explanations in science seem to be connected to whether students see knowledge as certain or not. If they can understand that the purpose of science is to provide explanations (based on interpretations) and not merely to describe phenomena, then they might be better able to grasp the idea of uncertainty. Subscales 2 and 3 were adapted from Stathopoulou and Vosniadou's GEBEP (2007). It is important to clarify that only the naming of the subscales was adapted. The content, as reflected in the items, was developed to attend to the three issues presented above and also to be appropriate for the participants of this study.

Simplicity. Three subscales were used to reflect simplicity of knowledge in science (25 statements and six scenarios): knowledge in science consists of cumulative factual piecemeal information vs. integrated complex systems of interrelated concepts (eight statements - six with positive and two with negative valence- / two scenarios); knowledge in science consists of single clear answers vs. multiple perspectives (ten statements - six with positive and four with negative valence - / two scenarios) and knowledge arises from knowable linear problem solving procedures vs. investigative back and forth procedures (eight statements - four with positive and four with negative valence - / two scenarios. Subscale 3 gauges knowledge of the iterative process of science. All subscales (not items though) were adapted from the GEBEP.

Source. It was conceptualized along the two subscales (16 statements and four scenarios): scientists copy existing knowledge vs. actively construct new knowledge (nine statements - four with positive and five with negative valence - / two scenarios); and knowledge is the result of an experiment vs. the explanation of the result of the experiment (seven statements - four with positive and three with negative valence - / two scenarios). Due to the fact that in this instrument students' views about their own learning in science were differentiated from scientists' work, these two subscales were newly developed. The focus of this dimension was strictly on students' views about scientists' work, therefore the scales relate to the construction of knowledge by scientists as an active or a passive way. Subscale 2 reflects the idea of active vs. passive construction of knowledge. Subscale 3 was developed to capture the view that knowledge does not simply lie within the results of an experiment but it is derived from of a scientist's interpretations of the results. This subscale underlines the active role of the scientist in the construction of knowledge.

Justification. Two subscales were developed to represent this dimension (18 statements and four scenarios): new knowledge is produced through experiments and other methods for collecting evidence vs. a scientist's smart ideas (12 statements - seven with positive and five with negative valence - / two scenarios) and experiments provide answers, proofs, theories, vs. experiments evaluate competing theories (six statements - three with positive and three with negative valence - / two scenarios)). Subscale 1 was included to elicit students' beliefs about the need to evaluate scientists' ideas through experiments. Subscale 2 was adapted from the GEBEP (Stathopoulou & Vosniadou, 2007) to evaluate students' views about the purpose of experiments. The purpose of this scale is to elicit information about whether students regard experiments as providing absolute truth, proving theories as right or wrong, or helping scientists choose among competing ideas and theories.

Item format

There were two parts in PESQ. Part A examined Explicit Personal Epistemology and consisted of a set of statements that required students to indicate degree of agreement / disagreement on a scale 1-5 (1=strongly disagree; 5=strongly agree). Part B examined Implicit Personal Epistemology and consisted of short scenarios that again required students to consider a conversation between two students and indicate with which party they agreed. Similar to Gill et al. (2004) it was assumed that personal epistemology can be examined at two levels: explicitly and implicitly. Personal epistemology is thus considered to be made explicit, if it is examined with statements that directly confront the participants with epistemological issues. For instance, the item 'Knowledge in science consists of simple unrelated facts' requires the respondent to think about the nature of knowledge in science (a conscious thinking process) and take a stance.

Scenarios on the other hand, examine personal epistemology indirectly, implicitly and less abstractly. The scenarios in Part B of the PESQ presented two children who seemed to disagree about issues related to one of the four dimensions of epistemology. The first child expressed a non-availing view about an epistemological issue related to one of the four dimensions, and the second child disagreed and laid out a corresponding availing view. Students were then required to state whether they agreed with the first child, the second or with both. It was assumed that by engaging in the conversation of the two children, participants would be better able to grasp the idea of each dimension, without having to think about the epistemological issue in the same direct manner as with explicit statements included in Part A of PESQ. The overall structure of Part B, as well as one scenario were adapted from the GEBEP (Stathopoulou & Vosniadou, 2007). One scenario was adapted from Hammer and Elby's (2006) EBAP instrument, while all the rest 18 scenarios were developed for this study. The structure (dimensions) and content (number of items and example items) of PESQ (Part A) is presented in Table 1. An example item of Part B is presented in Table 2.

Table 1

The Personal Epistemology in Science Questionnaire (PESQ) (Part A): dimensions, subscales and example items

Dimension/Subscales	Example items
Certainty	
purpose of science is to provide explanations provide a picture of the world (6)	Scientists focus on referring and describing natural phenomena, e.g. they vs. vs. refer to ice melting at the poles
knowledge certain and unchanging vs. tentative and evolving (15)	Scientists try to better explain physical phenomena and they may conclude that certain things we already know may be wrong and need to be changed
absolute truth vs. interpretation attempts (7)	Nature is complicated and thus scientists will never know with certainty al the secrets of nature
Simplicity	
cumulative factual piecemeal information vs. integrated complex systems of interrelated concepts (8)	Knowledge in science consist of simple unrelated facts
single clear answers vs. multiple perspectives (10)	Different scientists may be asked for a topic related to their domain of expertise and give different answers
knowable, linear problem solving procedures vs. investigative back and forth procedures (8)	Scientists always follow the same research procedures
Source	
scientists copy existing knowledge vs. actively construct new knowledge (10)	Knowledge in science is so extensive nowadays that scientists cannot discover new things
knowledge is the result of the experiment vs. the explanation of the result of the experiment (7)	The results of an experiment are self-evident and thus interpretations are not needed
Justification	
new knowledge is produced through experiments and other methods for collecting evidence vs. a scientist's smart ideas (12)	Scientists' smart ideas can be considered theories
experiment as providing answers, proofs, theories vs. evaluating competing theories (6)	If scientists conduct experiments very carefully, they may discover the absolute truth for the particular topics they study

Note. Number of items of each subscale is shown in parentheses.

Table 2

An example of a scenario in PESQ (Part B)

Vassilis and Stefanos disagree about truth in science

Vassilis: There are so many research projects underway that I am sure we will know the absolute truth for all physical phenomena. We will know everything with certainty. Otherwise, scientists' work has no sense.

Stefanos: I disagree. No matter how many research projects are conducted, absolute truth will never be discovered. Scientists will manage however, to better understand certain physical phenomena. This does not mean that they will discover the absolute truth for the phenomena they examine.

Vassilis: I believe that if scientists conduct an experiment really carefully they can discover the absolute truth for a particular phenomenon.

With whom do you agree?

A. I agree almost entirely with Vassilis

B. I agree more with Vassilis, but I think Stefanos makes some good points

C. I equally agree with both

D. I agree more with Stefanos, but I think Vassilis makes some good points

E. I agree almost entirely with Stefanos

Note. This scenario refers to the Certainty dimension of PESQ.

It should be noted that the 88 items of Part A were divided into two tests of equal number of items resulting in two versions with 44 items each. Each dimension, subscale and valence of items were equally represented in the two versions. Similarly, the 21 items of Part B were divided into two tests resulting in two versions. Version A consisted of 11 items and Version B of ten items.

Prior Knowledge in Science Test (PKST)

Content of PKST. Within the context of this pilot study the Prior Knowledge in Science Test (PKST) was also tested. This instrument was developed to tap students' knowledge of fifth grade science content that consists of 11 units. Units refer to topics like properties of matter, dilution, electrical circuits, adaptation and functions of plants and animals, photosynthesis, ecology (e.g. benefits of recycling), human digestive system and how eyes work. The teacher's guide provides exact required instruction time for each unit that ranges from two 80´ class periods to four 80´ class periods. In order to provide a weighted representation of each unit on the basis of required instruction time, it was decided to include about one question for each required 80´class period. Care was taken to include questions, wherever possible, that referred to knowledge, understanding and application, taken from Bloom's taxonomy of learning in domains (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Table 3 presents number of items for each unit and identifies for each item the corresponding cognitive level (knowledge, comprehension, and application). The resulting instrument consisted of 35 items.

Table 3

Content of the Prior Knowledge in Science Test (PKST)

Units	Knowledge	Comprehension	Application	Total
Friction (4x80')	1	2	1	4
Plant processes (4x80')	2	1	1	4
Animal categories & Adaptation (3x80')	1	2	-	3
Digestive System (3x80')	2	1	-	3
Eyes-Vision (3x80')	1	1	1	3
Thermal expansion & Contraction (3x80')	1	1	1	3
Solutions & Mixtures (2x80')	1	1	-	2
Mirrors, Images & Symmetry (3x80')	-	2	1	3
Static electricity (2x80')	2	1	-	3
Dynamic electricity (4x80')	1	2	2	5
Environment (2x80')	-	2	-	2
Total	12	16	7	35

Note. Instruction time in parentheses.

Structure of PKST. The test included eight true/false items, five multiple choice items, one fill-in the blanks (two-part question), seven short answer items (one item was a two-part question) and two matching items. Two items required description of experiments (materials and process) to test stated hypotheses and four items required underlining of options that applied to given questions. One of these questions ("To which forms does electricity transform in a TV?") provided four options (A: heat; B: Light; C: Sound, and D: Movement) and asked students to underline the options that applied, noting that there could be more that one right option. Six items required some form of drawing. For instance, one of these questions asked the drawing of light reflected from a mirror. Another question of the same type asked students to draw a line in a circuit to point the position of a wire that could cause a short-circuit. This particular question was followed by an explanation subquestion.

Participants

One hundred sixty seven students (78 boys and 89 girls) attending sixth grade completed the PESQ and PKST during the spring of the 2009-2010 school year. Participants were recruited from six suburban Nicosia schools and nine different classes. Data from students whose native language was not Greek, or/and attended special education classes were excluded from the study.

Procedure

The PESQ was administered to all the students of each class at a convenient class time after arrangement with school principals and sixth grade class teachers. Students were told that they would complete a questionnaire related to science. Also, they were explicitly told that there were not right or wrong answers for the items they would complete and that their honest opinion mattered greatly. Students were given one class period (40') to complete Part A of the instrument and another class period to complete Part B (on a different day). Half the students received Version A of Part A and half the students received Version B of Part A. The same day that Part A of PESQ was administered, students also completed PKST. In six classes the instrument was administered by the author of this manuscript and in the remaining three classes by the class teacher. The person who administered the instruments supervised the process and was available to respond to students' questions in regard to unknown words or phrasing of items.

Results

Rasch analysis was undertaken to revise and refine PESQ. Rasch analysis informs a test developer about the alignment of the data with the assumption that individuals' performance on the test and the difficulty of the test items form a stable sequence along a single continuum (Bond & Fox, 2001). In developing an instrument appropriate for younger students at the age of 11-12, information about the overall fit between the performance of the students and the level of difficulty of the items was crucial. Given that Rasch analysis situates performance and item difficulty along the same continuum, it reveals information about the level of difficulty of each item (and thus how appropriate the item is for the particular sample) and also provides information about the individuals who may successfully answer specific items and those who may fail those items. The analysis specifies an individual's position on the continuum which is informative of the items that this person may answer with success and items that the person may fail. There is a high probability that the person may answer with success items at or below the individual's position on the continuum and there is a low probability of success for items above that position (Bond & Fox, 2001). Thus, Rasch analysis indicates items that are beyond the capabilities of the particular individuals (highly difficult items) and items that seem to be under their capabilities (very easy items). Within the context of the present study such information was important in the revision process of a personal epistemology instrument suitable for younger students, in that very difficult items could be removed from the instrument and very easy items could be revised to meet the lower end of the capabilities of the particular population.

Iterative cycles of test refinement resulted in the current state of PESQ. Rasch analysis of data collected within the context of the small-scale pilot study (N=57) conducted in the spring semester of 2007-2008 revealed that a previous version of the questionnaire was highly unreliable. It was assumed that a large proportion of the unreliability could be attributed to lack of distinction between students' efforts in learning science from scientists' work in science as this was reflected in items related to source and justification of knowledge. Moreover, the difficulty of certain items was very high and thus such items were either excluded or simplified. Also, vocabulary and language were further simplified and examples were added to certain items. The version that emerged resulted in the version of PESQ that was pilot tested.

Rasch analysis output produces two indices of reliability, the item reliability index and the person reliability index. The idea of person and item ordering along the same continuum is important in interpreting reliability indices. The item reliability index represents an Item Separation Index and refers to the expected replicability of item ordering if these particular items were administered to another sample with comparable ability estimates. The person reliability index represents a Person Separation Index and refers to the expected replicability of person ordering, if the particular sample was given another set of items measuring the same construct. These indices represent the proportion of variance considered to be true. A high item reliability index indicates a satisfactory spread of both difficult and easy items and also that we can place confidence in the consistency of such inferences (Bond & Fox, 2001). A high person reliability index indicates a well matched test that consists of items that correspond to the performance of both high ability and low ability students.

PESQ (Part A). The original attempt to analyze PESQ using the Quest software (Adams & Khoo, 1996) for Rasch analysis indicated that Part A of the questionnaire was again highly unreliable (Item reliability index=.00). Inspection of item thresholds revealed that certain response categories (from the 5-point likert scale that was originally used in the questionnaire) were not adequately distinguished by the respondents. Note that only the two ends of the scale were labeled in the questionnaire; 1 was labeled as strongly disagree while 5 was labeled as strongly agree. Response categories 3, 4, 5 were not adequately distinguished as indicated by threshold values less than .80. Certain threshold values between response categories 1and 2 were also less than .80. Threshold values between categories 2 and 3 were acceptable (>.80). According to Bond and Fox (2001) when response categories do not seem to be adequately distinguished, then categories should be merged and data be reanalyzed. Therefore, it was decided to merge categories 1 (strongly disagree) and 2 (was not labeled in the questionnaire) into a single category labeled as 0 (disagree) and categories 3 (not labeled), 4 (not labeled) and 5 (strongly agree) into another single category labeled as 1 (agree). Recoding thus, resulted in a set of dichotomous data, which were reanalyzed using the same technique. This second round of analysis indicated that PESQ with dichotomous response options (agree/disagree) yielded a good model fit and relatively high item reliability. Table 4 provides a summary of the scale statistics. Item reliability was high (.93), while person reliability was acceptable (.74) indicating that we can place more trust in consistency of item positioning with a different sample, than person positioning with another set of related measures. In the process of an instrument development and refinement, item reliability index is more important than the person reliability index. Infit mean squares and outfit mean squares were near one and the values of infit t-scores and outfit t-scores were close to zero for both person and item statistics. Figure 2 presenting the overall fit between item difficulty and person ability shows that there was relatively good fit between item difficulties and person abilities, with only three items (items 1, 50, 5) seeming to be highly difficult for this particular sample.

Table 4

Statistics related to Part A of the Personal Epistemology in Science Questionnaire

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Items						
0.00	0.90	0.93	1.00	1.03	-0.13	0.07
Persons						
-0.16	0.54	0.74	0.99	1.03	-0.07	0.03

```
--------------------------------------------------------------------------
Availing Personal Epistemology         Difficult items
  4.0                                |
                                     |
                                     |
                                     |
                                     |     1
                                     |
                                     |
                                     |
  3.0                                |
                                     |
                                     |    50
                                     |     5
                                     |
                                     |
                                     |
                                     |
  2.0                                |
                                X    |
                                     |    12
                                     |
                                     |    33     36     46     87
                                     |     7     49
                               XX    |    69
                             XXXX    |    25
  1.0                     XXXXXXX    |
                              XXX    |    30     56     63     81
                                X    |    19     68     75     82
                         XXXXXXXX    |    45
                                X    |    10     52     78
                     XXXXXXXXXXXX    |    38     54     59
                        XXXXXXXXX    |    40     79
   .0           XXXXXXXXXXXXXXXXX    |    11     14     17     41
                     XXXXXXXXXXXX    |     8      9     31     35     43
                XXXXXXXXXXXXXXXXXXXXX|     2      4      6     42     64
                     XXXXXXXXXXXX    |     3     20     22     27     29
                         XXXXXXXX    |    13     37     39     76
                       XXXXXXXXXX    |    24     28     55     83     84
                 XXXXXXXXXXXXXXXXXXX |    60     66
                                X    |    18     32     48     62     67
 -1.0                     XXXXXXX    |    21     26     44     57     65
                            XXXXX    |    16     23     58
                              XXX    |    15
                              XXX    |
                                     |    72
                                     |    51
                                X    |    61
                                     |
 -2.0                           X    |
                                     |
Non-Availing Personal Epistemology    Easy items
--------------------------------------------------------------------------
```

Figure 2. Scale for PESQ (Part A); (N=167 and L =88 items)
Note. Each x represents 1 student

PESQ (Part B). The same Rasch analysis was undertaken to analyze data collected with Part B of PESQ (scenarios). Results indicated that Part B of PESQ remained highly unreliable. Attempts were made to recode these data using the same strategy that was used for

Part A of PESQ. However, no improvement in reliability was observed. The graph produced by Rasch analysis indicated a mismatch between item difficulty and person performance, indicating that students may have found this part of PESQ relatively easy. This was attributed to the presentation of the scenarios that proceeded in a predictable way for all scenarios: the first child expressed a non-availing view while the second expressed an availing view. Moreover, text length between the responses of the two children was disproportional, in favor of the child who expressed the availing view. It was reasoned that perhaps students identified these patterns in the presentation of the discussion of the two children and managed their answers accordingly. This resulted in a set of items of limited difficulty that did not match the full spectrum of students' abilities. Consequently, model fit was poor and reliability approximated zero.

PESQ Validity. In terms of examining the content validity of PESQ a group interview of four sixth grade students was conducted. Four items were selected from Part A and 4 items from Part B (one item for each dimension). The interview was about one hour long. Items taken from the instrument were read aloud to students who were asked to respond freely. Interview was transcribed and students' responses to the interview context were compared to the responses they gave on the same items when they had completed the instrument in class. One student was 100% consistent, two students were 75% consistent, while the fourth student was 50%. It is noteworthy that the students who seemed to be more consistent were those who originally had endorsed availing views when completing the instrument, while those who had endorsed less availing views when completed the instrument reverted to more availing views within the course of the interview context.

Four-dimensional structure. A model of a four-dimensional structure of personal epistemology was tested using the Rasch analysis. Table 5 shows that item reliability was satisfactory (higher than .85 in all dimensions). Person reliability was however lower. Infit mean squares were near one, but outfit mean squares were rather higher. Moreover, despite that the majority of infit t values approximated the expected value of zero, certain outfit t values were out of range (e.g. item outfit t of the Source dimension).

Table 5

Statistics related to the four dimensions

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Certainty						
Items						
0.00	1.00	0.93	1.00	1.05	0.00	0.09
Persons						
-0.70	0.48	0.34	1.00	1.04	-0.03	0.08
Simplicity						
Items						
0.00	0.63	0.87	1.01	1.05	-0.11	-0.02
Persons						
0.05	0.63	0.42	0.99	1.03	0.08	0.14
Source						
Items						
0.00	0.92	0.92	1.01	1.08	-0.03	0.16
Persons						
0.39	0.69	0.41	0.98	1.04	0.02	0.15
Justification						
Items						
0.00	0.87	0.92	1.00	1.02	-0.14	0.02
Persons						
-0.07	0.68	0.51	0.99	1.05	0.00	0.13

Prior Knowledge in Science Test (PKST). This test examined students' domain knowledge in science. In particular it examined students' knowledge on fifth grade science content. Each correct response received a score of 1 and each incorrect response received a score of 0. Correct two-part short-answer questions received a score of two points and matching items received one point for each correct matching. For instance, one of the matching items included four matching pairs. Each correct matching pair received one point. Thus, four points were given for four correct pairs, three points for three, etc. The items that required description of experiments (materials and process) to test stated hypotheses received one point for materials and one point for process. The items that required underlining of options that applied to given problems received one point for each correct option. This type of scoring treated each question, or subquestion independently and consequently for the purposes of the analysis the total number of items appeared to be 58. Rasch analysis indicated that the test was both item and case reliable. Table 6 summarizes scale statistics. Item reliability was .97 and case reliability was .86. Infit mean squares and outfit mean squares were near one, while infit and outfit t values approximated zero. Inspection of Figure 3 pinpointed a few difficult items (34, 50, 35, 32, 33, 31) that were either modified or excluded from the final version of the test.

Table 6

Statistics related to the Prior Knowledge in Science Test (PKST)

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Items						
0.00	1.42	0.97	1.00	0.96	-0.07	-0.02
Persons						
-0.16	0.78	0.86	1.01	0.96	0.01	0.03

```
------------------------------------------------------------------------------
High Knowledge of 5th grade science    Difficult items
  5.0                                  |
                                       |   34
                                       |
                                       |
                                       |
                                       |   50
  4.0                                  |
                                       |
                                       |   35
                                       |
                                       |
                                       |
  3.0                                  |
                                       |
                                       |
                                       |
                                       |
  2.0                                  |
                                       |   32     33
                                       |   31
                                       |
                                       |
                                 XXX   |   53
  1.0                              X   |   58
                                 XXX   |
                           XXXXXXXXX   |   28     30     55     56
                                 XXX   |   12     17     27     44     48
                              XXXXXX   |   21     39     41     42
                           XXXXXXXXX   |   10     25     51     52
                           XXXXXXXXX   |   18     29     47
   .0                     XXXXXXXXXX   |    3     19
                           XXXXXXXXX   |   20     36     37     49
                   XXXXXXXXXXXXXXXXX   |    6     40
                XXXXXXXXXXXXXXXXXXXX   |   43
                                XXXX   |
                     XXXXXXXXXXXXXXX   |   15     45     46
 -1.0                  XXXXXXXXXXXXX   |   14     24
                               XXXXX   |    4      5      7
                           XXXXXXXXX   |   16
                                  XX   |    8     38
                              XXXXXX   |    9     13     23     26
                             XXXXXXX   |    2     11
 -2.0                                  |   22
                                 XXX   |
                                  XX   |    1
                                   X   |
                                       |
 -3.0                                  |
                                   X   |
                                       |
                                       |
                                       |
 -4.0                                  |
Low Knowledge of 5th grade science    Easy items
------------------------------------------------------------------------------
```

Figure 3. Scale for PKST (N=167 and L =58 items)
Note. Each x represents 1 student

Brief Discussion

PESQ with a 5-point likert scale was highly unreliable for the particular sample, while a dichotomous agree/disagree response pattern yielded relatively reliable data. These results indicated that students at the age of 12 years old might not be able to consistently respond to the particular items distinguishing between a 3 and 4 for instance. Given that when students at this age may consider their epistemic views for the first time as they complete such instruments, a dichotomous response agree/disagree scale was considered more appropriate. In regard to Part B of PESQ in order to minimize any extraneous order effects, it was decided to vary the order of the child who expressed an availing view throughout the instrument. Moreover, more text was added to the words expressed by the child who stated the non-availing view.

Main Study

Research Design

Personal Epistemology (Explicit and Implicit) represented the dependent variable of the study and Text Type was the independent variable with three levels: baseline text, refutation text and analogy text. The contribution of Interest, Prior Knowledge and Text Comprehension on the dependent variable was examined in order to utilize them as possible covariates. A repeated measures analysis of covariance was performed for each of the two levels of Personal Epistemology (Explicit and Implicit). As a result, a repeated measures analysis of covariance (RM-ANCOVA) was conducted with Time as the within subjects factor with two levels (Explicit Personal Epistemology at the Pretest and the Posttest). Text Type represented the between subjects factor and Text Comprehension was used as the covariate. The same RM-ANCOVA was also performed for Implicit Personal Epistemology. A multivariate analysis of covariance (MANCOVA) was conducted to examine the impact of Interest and Prior Knowledge on Comprehension.

Participants

The students involved in the study were initially 212 sixth grade students (11-12 years old) attending 12 classes in five public elementary schools. Students were primarily Greek-Cypriots coming mainly from middle-class families. Students needed to return a consent form signed by their parents in order to participate. It should be noted that there were nine students characterized by their teachers as struggling students, with limited text comprehension ability. Although those students were administered the same materials with the other participants of the study, their data were excluded from statistical analysis. The interventions in this study were text-based and one needed to be able to comprehend texts in order to take advantage of the interventions. Moreover, six students who did not complete their post-tests with the appropriate attention and five students who were absent at the day of the intervention were also removed from the total sample. Lastly, there were 17 students who were absent either at the day of the pre-test or the post-test. There were therefore 175 students (85 boys, 90 girls) who participated in the intervention and also provided data both at the pre-test and the post-test. Students of each participating class were assigned to one of the three text groups randomly.

Materials

Personal Epistemology in Science Questionnaire (PESQ). PESQ consisted of two parts. Part A (Explicit Personal Epistemology) consisted of 87 agree/disagree statements and Part B (Implicit Personal Epistemology) consisted of 20 scenarios. All items (statements and scenarios) were structured under the four dimensions of certainty, simplicity, source and justification. Three subscales were used to reflect certainty (28 statements and seven scenarios), and three subscales were used to reflect simplicity (25 statements and five scenarios). Moreover, two subscales represented source (16 statements and four scenarios) and two subscales represented justification (18 statements and four scenarios). There was about an equal number of items of positive and negative valence in each subscale. Also, there were two versions of each part of the instrument. Each dimension and each subscale were equally represented in the two versions, and the two versions were comparable in terms of total number of items. There were 43 statements in version A and 44 statements in version B of Part A. Both versions of Part B consisted of 10 scenarios each.

With respect to the content of PESQ, statements in Part A explicitly asked participants to indicate whether they agreed or disagreed with statements about the four dimensions of epistemology. For instance, students were required to indicate whether they agreed or disagreed with statements such as “Nature is complicated and thus scientists will never know with certainty all the secrets of nature” (Table 1). Scenarios (about 100 words long on average) presented the discussion of two children who seemed to disagree about topics in science that corresponded to epistemological issues related to the four dimensions. One of the two children expressed an availing view, while the other expressed a non-availing view. Students were asked to indicate whether they agreed with the first child; more with the first but also to some extent with the second child; equally with both children; more with the second but also to some extent with the first child; or agree with the second child (see Table 2 for an example item). The scenarios presented students who expressed availing views in random order to avoid the problems that were presented in the pilot study with respect to presentation order (Appendix A presents the two versions of Part A and Appendix B presents the two versions of Part B).

Negative valence items were recoded in both parts of the instrument. Rasch analysis was undertaken to establish the reliability of each of the two parts of PESQ for each of the two testing times using the Quest software (Adams & Khoo, 1996). It has been previously discussed that Rasch analysis orders items and people on a single continuum and provides information about (a) a satisfactory spread of both easy and hard items, indicated by the item reliability index (that represents an Item Separation Index), and (b) a satisfactory alignment of item difficulty with person performance, indicated by the person reliability index (that represents a Person Separation Index). The higher the value of the Item Separation Index, the higher the confidence we can place in the replicability of the exact ordering of items in an administration of the test to other samples with the same characteristics. The higher the value of person reliability index the higher the trust we can place on obtaining the same person ordering if the same sample was administered a similar test (Bond & Fox, 2001). Both indices represent the proportion of variance considered to be true. For the purposes of designing and developing an instrument the item reliability index would be more informative. The person reliability index is however more useful when the intention is to ensure a reliable set of data of a particular sample on a particular variable.

Part A of PESQ (Explicit Personal Epistemology). Analysis of Explicit Personal Epistemology data at both the Pretest and the Posttest indicated a good model fit at both testing times. Table 7 provides a summary of the scale statistics related to both the Pretest and the Posttest.

Table 7

Statistics related to Part A of Personal Epistemology in Science Questionnaire at the Pretest and the Posttest

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Pretest						
Items						
0.00	1.11	0.95	1.00	0.99	0.11	0.05
Persons						
0.98	0.58	0.70	0.99	0.99	0.06	0.02
Posttest						
Items						
0.00	1.08	0.94	1.00	0.98	0.12	-0.01
Persons						
1.07	0.70	0.77	0.98	0.98	0.08	0.03

Table 7 indicates that Part A of PESQ that examined Explicit Personal Epistemology was reliable at the item level both at the Pretest and the Posttest. Item and person reliability estimates were satisfactory both at the Pretest and the Posttest. Infit Mean Squares and Outfit Mean Squares were near the expected value of one, while infit t and outfit t approached the expected value of zero indicating a relatively good model fit. Figure 4 presents the hierarchy of persons and items along the continuum of Explicit Personal Epistemology at the Pretest and Figure 5 presents the same continuum at the Posttest. Both figures illustrate that person performance was higher than the overall difficulty of PESQ (indicated also by the high person mean at the Pretest, *M*=0.98 and the Posttest, *M*=1.07).

```
--------------------------------------------------------------------------
Availing Personal Epistemology         Difficult Items
  4.0                            |
                                 |       1
                                 |
                                 |
                                 |
                                 |      49
                                 |
                                 |
                                 |       5
  3.0                        X   |
                                 |
                                 |      45
                                 |
                             X   |
                             X   |
                           XXX   |
                          XXXX   |
                             X   |      12     51     68
  2.0                     XXXX   |
                          XXXX   |
                 XXXXXXXXXXXXX   |
                             X   |      86
                 XXXXXXXXXXXXX   |      32     35
                       XXXXXXX   |      67
                           XXX   |
            XXXXXXXXXXXXXXXXXX   |
              XXXXXXXXXXXXXXXX   |
  1.0       XXXXXXXXXXXXXXXXXX   |       7     80
                   XXXXXXXXXXX   |      25     48
                    XXXXXXXXXX   |
                                 |      73
                    XXXXXXXXXX   |      36     40     81
                       XXXXXXX   |
                    XXXXXXXXXX   |      19     44     52     55     77
                    XXXXXXXXXX   |      10     42     58     62     78
                  XXXXXXXXXXXX   |      37     53
                 XXXXXXXXXXXXX   |      70     74     87
   .0                   XXXXXX   |       2      9     29     41     54
                           XXX   |      33     34     39     75
                                 |      11     30     72
                             X   |       3     14     17     46     69
                                 |      13     47
                           XXX   |      22     56     64     79
                                 |      24     27     63     82     85
                                 |       6      8     20     26
                                 |      15     18     50     65
 -1.0                            |       4     16     43     57     59
                                 |      23     28     31     83
                                 |      21     38
                                 |
                                 |      76
                                 |      66
                                 |      60     71
                                 |
 -2.0                            |
Non-Availing Personal Epistemology       Easy items
--------------------------------------------------------------------------
```

Figure 4. Scale for PESQ (Part A) at the Pretest (N=212 and L =87 items)
Note: Each x represents 1 student

```
----------------------------------------------------------------------------------
Availing personal epistemology        Difficult Items
  5.0                              |
                                   |
                                   |
                                   |
                                   |
                                   |     1
  4.0                              |
                                   |
                                   |
                                   |
                              X    |
                                   |
                                   |     5
                              X    |
  3.0                              |
                              X    |    49
                             XX    |
                                   |
                        XXXXXXX    |
                              X    |    45
                           XXXX    |    51
                      XXXXXXXXX    |    12     35     68     86
  2.0               XXXXXXXXXXX    |
                         XXXXXX    |
                          XXXXX    |
                   XXXXXXXXXXXX    |    32
                          XXXXX    |
                    XXXXXXXXXXX    |
                      XXXXXXXXX    |
  1.0            XXXXXXXXXXXXXX    |     7     48     80
                  XXXXXXXXXXXXX    |    55     67
                        XXXXXXX    |    25
                 XXXXXXXXXXXXXX    |    10     36     53     73
                     XXXXXXXXXX    |     9     81
                   XXXXXXXXXXXX    |    30     62     78
                   XXXXXXXXXXXX    |    34
                         XXXXXX    |    19
   .0                  XXXXXXXX    |     3     44     52     77     79
                       XXXXXXXX    |    40     69     70
                              X    |    14     28     29     33     39
                             XX    |    13     26     42     43     58
                              X    |    11     21     27     37     47
                              X    |    22     41     56     84
                              X    |     2     24     83
                                   |     6     18     31     59
 -1.0                              |     4      8     38     57     60
                                   |    15     17     20     23     61
                                   |    71
                                   |    65
                                   |    82
                                   |    50
                                   |
                                   |    16
 -2.0                              |
Non-Availing Personal Epistemology      Easy items
----------------------------------------------------------------------------------
```

Figure 5. Scale for PESQ (Part A) at the Posttest (N=195 and L =87 items)
Note: Each x represents 1 student

Part B of PESQ (Implicit Personal Epistemology). Reliability at the item level was poor both at the Pretest and the Posttest (.00) despite the fact that there were no items or students who did not fit the resulting model well. Reliability at the person level was acceptable for both the Pretest and the Posttest (.48 and .64 respectively). A strategy that was employed in the pilot study in order to deal with the issue of low reliability, supported by Bond and Fox (2001), was to recode and reanalyze data. There were five response categories in Part B of PESQ, one to five, one denoting no endorsement of an availing view and five denoting a high endorsement of an availing view. It was decided to recode both the 1 and 2 response categories into zero, the response category 3 into one and the response categories 4 and 5 into 2. Data were reanalyzed with the new coding (0, 1, 2) and analysis indicated that item reliability remained poor both at the Pretest and the Posttest, while there was a small decrease in the person reliability both at the Pretest and the Posttest (.47 and .53 respectively). This coding did not match the data well either. Consequently a new attempt was undertaken to recode categories 1,2,3 into 0 and response categories 4 and 5 into 1. The reasoning behind this recoding was that it distinguished people who did not endorse the availing view (and selected thus either one of the three response categories 1,2,3) from people who endorsed it (and selected either 4 or 5). Analysis of recoded data yielded improved item reliability estimates both at the Pretest and the Posttest (.88 and .83 respectively). Person reliability estimates remained overall the same both at the Pretest and the Posttest (.50 and .57 respectively). Infit and outfit mean squares are near one and infit t and outfit t approximate zero, although the persons outfit t both at the Pretest and the Posttest are larger than expected. Statistics related to the resulting model with the recoded data of Implicit Personal Epistemology are summarized in Table 8.

Table 8

Statistics related to Part B of Personal Epistemology in ScienceQuestionnaire at the Pretest and the Posttest

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Pretest						
Items						
0.00	0.60	0.88	0.98	0.98	-0.04	0.04
Persons						
0.68	0.69	0.50	1.00	1.00	0.06	0.11
Posttest						
Items						
0.00	0.51	0.83	0.99	0.97	-0.05	-0.08
Persons						
0.51	0.79	0.57	1.00	0.99	0.08	0.12

Figure 6 indicates that at the Pretest, item difficulty was not well aligned with person performance. Item difficulty was lower than person performance while at the same time there was also a small number of students whose performance was lower than the item difficulty of the easy items (items 2, 3, 4).

```
--------------------------------------------------------------------------------
Availing Personal Epistemology       Difficult Items
  3.0                            |
                                 |
                                 |
                         XXXXX   |
                                 |
                             X   |
                                 |
                                 |
                                 |
  2.0                            |
                   XXXXXXXXXXX   |
                                 |
                             X   |
                                 |
                                 |
             XXXXXXXXXXXXXXXXX   |
                             X   |
                                 |       9
  1.0                            |
                  XXXXXXXXXXXX   |
                             X   |      13
                                 |       1      6
                      XXXXXXXX   |      15
                       XXXXXXX   |       5
                                 |       8     16
                                 |       7
                  XXXXXXXXXXXX   |
   .0                        X   |      18     19
                                 |
                   XXXXXXXXXXX   |      14
                                 |      11
                             X   |
                      XXXXXXXX   |      20
                                 |      12     17
                             X   |      10
                             X   |       3      4
                           XXX   |       2
 -1.0                            |
                                 |
                                 |
                             X   |
                                 |
                                 |
                                 |
                                 |
                                 |
 -2.0                            |
                                 |
                                 |
                             X   |
                                 |
                                 |
                             X   |
                                 |
                                 |
 -3.0                            |
Non-availing personal epistemology   Easy Items
--------------------------------------------------------------------------------
```

Figure 6. Scale for PESQ (Part B) at the Pretest (N=195, L=87)
Note. Each X represents 2 students

Similar issues were observed in the Posttest. Figure 7 illustrates the same issue of alignment. A number of people were situated higher than item 9 (considered a difficult item compared to the rest), while there were also students below item 2 (considered an easy item).

```
--------------------------------------------------------------------------------
Availing Personal Epistemology      Difficult Items
  3.0                            |
                                 |
                                 |
                     XXXXXXXXX   |
                        XXXXXX   |
                                 |
                                 |
                                 |
                                 |
  2.0                            |
                         XXXXX   |
                     XXXXXXXXX   |
                                 |
                                 |
                                 |
                    XXXXXXXXXX   |
                       XXXXXXX   |
                            XX   |
  1.0                        X   |
                        XXXXXX   |       9
                   XXXXXXXXXXX   |
                             X   |
                                 |      15
  XXXXXXXXXXXXXXXXXXXXXXXXXXXX   |      16
                             X   |       6      7      8     13      19
                             X   |       1
 XXXXXXXXXXXXXXXXXXXXXXXXXXXXX   |       5     18
   .0                            |
                                 |
          XXXXXXXXXXXXXXXXXXXX   |      14     20
                                 |      11
                                 |       3     12
                     XXXXXXXXX   |
                     XXXXXXXXX   |       4
                                 |      17
                                 |
                      XXXXXXXX   |      10
 -1.0                            |
                                 |
                                 |       2
                            XX   |
                             X   |
                                 |
                                 |
                             X   |
                             X   |
 -2.0                            |
                                 |
                                 |
                             X   |
                                 |
                                 |
                             X   |
                                 |
                                 |
 -3.0                            |
Non-availing personal epistemology   Easy Items
--------------------------------------------------------------------------------
```

Figure 7. Scale for PESQ (Part B) at the Posttest (N=185, L=87)
Note. Each X represents 2 students

The four-dimensional structure in PESQ (Part A). Rasch analysis was again undertaken to examine whether the four-dimensional structure could be supported for both the Pretest and the Posttest. Table 9 summarizes statistics related to the four dimensions in Explicit Personal Epistemology at the Pretest. Item reliability estimates were relatively high for all four dimensions, while person reliability estimates ranged from moderate to low. The four-dimensional structure was examined with data provided by both parts of PESQ. It should be noted however, that the four-dimensional structure was not supported by the data that corresponded to Implicit Personal Epistemology at either the Pretest or the Posttest.

Table 9

Statistics related to the hypothesized four dimensions of Explicit Personal Epistemology at the Pretest

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Certainty						
Items						
0.00	1.33	0.96	1.00	1.07	-0.01	0.17
Persons						
0.51	0.58	0.45	0.99	1.07	-0.02	0.08
Simplicity						
Items						
0.00	1.04	0.94	1.00	0.97	0.15	-0.03
Persons						
1.13	0.57	0.36	0.99	0.96	0.10	0.10
Source						
Items						
0.00	0.84	0.90	1.00	1.01	0.07	0.14
Persons						
1.25	0.00	0.00	0.99	1.00	0.12	0.17
Justification						
Items						
0.00	1.20	0.95	0.99	1.08	-0.10	0.06
Persons						
1.16	0.70	0.38	0.95	1.10	0.01	0.18

Table 10 summarizes scale statistics related to Explicit Personal Epistemology at the Posttest. Similar to the results of the analysis of Explicit Personal Epistemology at the Pretest, item reliability remained satisfactory for all four dimensions, while person reliability ranged from average to low. Infit t and outfit t were higher than expected in the dimensions of simplicity, source and justification.

Table 10

Statistics related to the hypothesized four dimensions of Explicit Personal Epistemology at the Posttest

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Certainty						
Items						
0.00	1.31	0.96	1.01	1.03	-0.03	0.01
Persons						
0.60	0.59	0.45	0.98	1.01	-0.03	0.08
Simplicity						
Items						
0.00	0.91	0.92	1.01	0.97	0.19	-0.03
Persons						
1.29	0.61	0.38	0.99	0.95	0.14	0.10
Source						
Items						
0.00	1.13	0.94	0.99	1.03	0.02	0.07
Persons						
1.24	0.58	0.28	0.98	1.03	0.06	0.18
Justification						
Items						
0.00	0.87	0.91	0.98	1.02	-0.13	0.02
Persons						
1.28	0.55	0.25	0.94	1.08	0.03	0.19

The four-dimensional structure in PESQ (Part B). Rasch analysis was undertaken to examine the hypothesized four-dimensional structure also in Implicit Personal Epistemology. Table 11 indicates that although the item reliability estimates for all four dimensions and fit indices are satisfactory, the person reliability estimates and fit indices are problematic. Person reliabilities for all four dimensions are equal to zero while infit t and outfit t are larger or smaller than the expected value of zero.

Table 11

Statistics related to the hypothesized four dimensions of Implicit Personal Epistemology at the Pretest

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Certainty						
Items						
0.00	0.62	0.86	1.00	1.01	-0.04	0.02
Persons						
0.28	0.00	0.00	1.00	1.01	0.07	0.18
Simplicity						
Items						
0.00	0.37	0.73	1.00	1.01	0.00	0.09
Persons						
0.34	0.00	0.00	1.00	1.01	0.06	0.19
Source						
Items						
0.00	0.74	0.85	0.99	0.99	-0.01	0.03
Persons						
0.17	0.00	0.00	1.00	1.00	0.02	0.16
Justification						
Items						
0.00	1.27	0.94	0.99	1.03	-0.11	0.08
Persons						
0.38	0.00	0.00	0.99	1.03	-0.07	0.13

Table 12 presents statistics related to the four dimensions of Implicit Personal Epistemology at the Posttest. The item reliability estimates for all four dimensions (except

Simplicity) as well as the related fit indices are satisfactory. However, person reliability estimates are equal to zero, while the associated infit t and outfit t are larger than zero.

Table 12

Statistics related to the hypothesized four dimensions of Implicit Personal Epistemology at the Posttest

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Certainty						
Items						
0.00	0.41	0.70	1.00	1.00	0.02	0.05
Persons						
0.07	0.00	0.00	1.00	1.00	0.07	0.19
Simplicity						
Items						
0.00	0.14	0.27	0.99	0.98	-0.02	-0.03
Persons						
0.23	0.00	0.00	1.00	1.00	0.14	0.21
Source						
Items						
0.00	0.69	0.83	1.01	1.02	-0.09	0.02
Persons						
0.12	0.00	0.00	1.00	1.00	-0.02	0.16
Justification						
Items						
0.00	1.53	0.95	0.99	1.01	-0.07	0.05
Persons						
0.31	0.00	0.00	0.99	1.02	0.02	0.18

*Brief Discussion. R*asch modeling builds on the idea of unidimensionality and provides information about the extent to which a given data set on a measured variable may support one higher order dimensional structure that may, however, encompass a set of interrelated subordinate structures (Bond & Fox, 2001). If a model seems to be supported using the Rasch modeling then it may be assumed that the construct represented by the model may be characterized as unidimensional. A unidimensional structure may however, consist of a number of subscales that ought to be interrelated. In this research, data provided by the main pilot study as well as the main study on sixth grade students' personal epistemology in science, support a unidimensional structure as indicated by overall satisfactory model fit indices. The unidimensional structure was supported both in data that represented Explicit Personal Epistemology and in data that represented Implicit Personal Epistemology. While item reliability estimates of the four dimensions of Explicit Personal Epistemology are adequate, person reliability estimates and the associated fit indices are problematic. In terms of Implicit Personal Epistemology, item reliability estimates of the four dimensions are adequate, but the person reliability estimates are equal to zero. Fit indices associated with person reliability are again problematic. As a result the four-dimensional structure is partially supported.

Moreover, in terms of the two different types of personal epistemology assessment, explicit and implicit, the implicit assessment was less reliable. Despite the revisions in the format of scenarios (that were used for the assessment of Implicit Personal Epistemology) after the main pilot study, improvement in reliability was small. Recoding the data derived from the 1-5 likert scale into dichotomous 0-1 data enhanced reliability. However, reliability of individual dimensions was equal to zero. Consequently, it was decided not to use data of the four dimensions of Implicit Personal Epistemology in any subsequent analyses. It should be noted that the Rasch standardized scores were used in all subsequent analyses presented in Chapter 4.

Prior Knowledge in Science Test (PKST). This test consisted of 33 items in total (see Appendix C). It consisted of eight true/false items, five multiple choice items, one fill-in the blanks (consisted of two parts), seven short answer items (one item consisted of two parts) and two matching items. One item required description of experiments (materials and process) to test stated hypothesis and four items required underlining of options that applied to given questions. One of those questions ("To which forms does electricity transform in a TV?")

provided four options (A: heat; B: Light; C: Sound, and D: Movement) and asked students to underline the options that applied, noting that there could be more that one correct options. Five items required some form of drawing. For instance, one of those questions asked for the drawing of light reflected from a mirror. Another question of the same type asked students to draw a line in a circuit to point the position of a wire that could cause a short-circuit. This particular question was followed by an explanation subquestion.

Each correct response received a score of 1 and each incorrect response received a score of 0. Correct two-part short-answer questions received a score of two points and matching items received one point for each correct matching pair. A correct matching pairs item, for instance, could receive a total of four points. The item that required description of an experiment (materials and process) received one point for correct materials and one point for correct process. The items that required underlining of options that applied to given problems received one point for each correct option. This type of scoring treated each question, or subquestion independently and consequently the maximum possible score was 63 (higher than the total number of items). To account for order effects, two versions of the same instrument were formed. Each version included the same items appearing however, in different order. Appendix C presents version A.

Rasch analysis of PKST yielded satisfactory reliabilities both at the item and the person level. Fit indices indicated a good model fit. Table 13 outlines statistics related to this test. Figure 8 illustrates that item difficulty and person performance were well aligned, indicating that Prior Knowledge was a well-matched test.

Table 13

Statistics related to the Prior Knowledge in Science Test

Mean	SD	Reliability	Infit Mean Square	Outfit Mean Square	Infit t	Outfit t
Items						
0.00	1.05	0.97	1.00	0.99	0.07	0.00
Persons						
0.23	0.69	0.85	1.00	0.99	0.02	-0.04

```
--------------------------------------------------------------------------
High Knowledge of 5th grade science    Difficult items
  4.0                            |
                                 |
                                 |
                                 |
                                 |
                                 |
                                 |      32
  3.0                            |
                                 |
                                 |
                                 |      31
                                 |
                             X   |
                                 |      63
                                 |
                                 |
  2.0                        X   |      28
                                 |
                                 |
                            XX   |
                            XX   |      62
                           XXX   |
                           XXX   |      27
                         XXXXX   |      10
                            XX   |       3     57
  1.0                    XXXXX   |
             XXXXXXXXXXXXXXXXX   |
                       XXXXXXX   |      41     48
                     XXXXXXXXX   |      12     17     25     38
                      XXXXXXXX   |      21     36     49
           XXXXXXXXXXXXXXXXXXX   |      55
                 XXXXXXXXXXXXX   |      39
                        XXXXXX   |      19
            XXXXXXXXXXXXXXXXXX   |      18     20     30
                 XXXXXXXXXXXXX   |       6     16     61
   .0             XXXXXXXXXXXX   |      34     37     47     58
                          XXXX   |       5     54
                       XXXXXXX   |       7     33     52     56
                       XXXXXXX   |      45
                        XXXXXX   |      14     15     40     43     50
                    XXXXXXXXXX   |      53     60
                         XXXXX   |       8     42     44     51
                          XXXX   |      29
                          XXXX   |
 -1.0                      XXX   |       2      9     46
                             X   |       4     24
                             X   |      13     26
                             X   |       1
                             X   |
                           XXX   |
                                 |      35
                             X   |      11     22     23
                                 |
 -2.0                        X   |
Low Knowledge of 5th grade science    Easy items
--------------------------------------------------------------------------
```

Figure 8. Scale for PKST (N=197 and L=63 items)
Note. Each x represents 1 student

Personal Interest in Science Questionnaire(PISQ). This instrument was developed to assess students' interest in science in different contexts. The main purpose of this 10-item instrument was to ask students to consider a very specific context in regard to science before responding. The first item presented the discussion of five students about science as a school subject. Each child expressed different degrees of preference about science, the first expressing a lack of interest about science and the fifth expressing a strong preference about it. The second item had the same structure but the discussion of the children referred to watching TV news related to science. The other eight items presented very short scenarios about aspects of school life and beyond where students needed to rate their preferences about five subjects: science, math, language, history and religion. The items dealt with topic preference in school projects, preferable TV programs, CD Roms, books, board games, websites, museums, etc. Students were asked to rate with the number 1 their most preferable choice and with number 5 their least preferable choice. The overall aim in developing this instrument was to maximize the use of pictures and minimize the use of text in order to keep students engaged throughout the completion of it.

Responses in the first two items that indicated agreement with the child that expressed a strong interest in science received five points, while agreement with the child that expressed lack of interest in science received one point (two, three and four points were given accordingly for responses falling between the two responses described above). The remaining eight items received five points for responses that rated science as the first preference, four points for responses that rated science as the second preference, three points for responses that rated science as the third preference, two points for rating science as the fourth preference and one point for responses that rated science last.

To account for order effects, two versions of the same instrument were formed. Each version included the same items appearing however, in different order. Appendix D presents version A of the Personal Interest in Science Questionnaire. Cronbach's alpha reliability analysis of the ten items resulted in a = .93.

*Situation Interest Measure***.** Situation interest reflected students' interest in reading the text and thus it was measured immediately after students completed reading. Each text was presented in four sections (each section dealt with one dimension of epistemology). Thus, students completed this on-line measure four times in total. The situation interest measure was adapted by a computerized version by Ainley et. al. (2002). It consisted of a single question followed by three response options. The question was:

"How interesting do you find the text that you have just read?" and the three response options were:  =very interesting,  =somewhat interesting,  =not interesting. Cronbach's alpha reliability analysis of this measure resulted in a = .78.

Intervention Texts

Three Text Types were used: (a) a baseline (control) text, (b) a refutation text, and (c) an analogy text. All three Text Types included exactly the same information about the four hypothesized dimensions of personal epistemology: Certainty, Simplicity, Source and Justification. The four dimensions were presented in four independent sections and each section could be read in any order. The topic of each section corresponded directly to one of the four dimensions. The certainty section in all three Text Types was preceded by the title 'Does knowledge in science change or remains stable?'. The simplicity section was preceded by the title 'Are different pieces in knowledge in science interrelated or unrelated to each other?'. The source section was titled 'What is the role of scientists' ideas in science?' and the justification section was titled 'What is the role of experiments and research in science?'.

In addition to the information related to the four dimensions that was common in al three Text Types, the refutation text presented non-availing views related to the epistemological theme of each section, along with refutations of those views that were subsequently followed by science-based explanations. In terms of the analogy text, in addition to the common information that was present in all three texts related to the four dimensions, it also included analogies between the epistemological theme discussed in each section and everyday life examples.

Three experienced sixth grade class teachers were asked to read all three Text Types and write the main idea of all four sections of each Text Type. The responses of the three teachers were contrasted in order to examine whether the main theme of each section was comparable across the three Text Types. Teachers' responses verified that despite the elaborations present in both the refutation and the analogy texts, the main theme of each section was consistent across the three Text Types.

Baseline Text (description of formal epistemology). The purpose of this Text Type was to present in expository text format the scientific view about the nature of science and the process of knowing in science. The four sections of this Text Type presented issues about the epistemology in science focusing on each of the four dimensions: Certainty, Simplicity, Source and Justification. The Certainty section consisted of 211 words structured in three paragraphs, the Simplicity section consisted of 266 words structured in four paragraphs. The Source section was 255 words long consisting of three paragraphs and the Justification section was 335 words long consisting of five paragraphs. The average number of words in each sentence was 23 (see Appendix E for all four sections of the baseline text).

Refutation Text (description of formal epistemology+refutation). This Text Type involved a refutation text structure that identified alternative conceptions, refuted them and presented the scientific explanations as more appropriate (Hynd, 2001). Each section of the refutation text that was used in this study introduced a non-availing view of personal epistemology associated with the topic of the section (i.e. Certainty, Simplicity, Source and Justification). The non-availing view was subsequently refuted and the refutation was supported by a science-based explanation that immediately followed. The Certainty section consisted of 536 words structured in seven paragraphs and the Simplicity section consisted of 511 words structured in seven paragraphs. The Source section consisted of 444 words structured in five paragraphs and the Justification section consisted of 618 words structured in eight paragraphs. The average number of words per sentence was again 23 words (see Appendix F for all four sections of the refutation text).

Analogy Expository Text (description of formal epistemology+analogy). The purpose of this Text Type was to help readers draw connections between aspects of everyday reasoning that they were familiar with (epistemological resources) and the scientific view of the nature of knowledge and knowing in science. This text represented an expository text enriched with analogies. Again, the discussion of each section focused on the four hypothesized dimensions of epistemology. In each section one or two epistemological resources (examples) were used as anchoring conceptions (Clement, Brown, & Zietsman, 1989) to the epistemological information introduced in the section. In particular, appropriate epistemological resources were identified with the help of seven sixth grade teachers. Lists of candidate resources for each targeted dimension were compiled and given to teachers who taught sixth grade for one or more years. Teachers were asked to review the provided examples (resources) and order them according to the extent they considered that the examples were part of sixth grade students' everyday thinking routines. Teachers were also asked to provide their own suggestions of candidate resources (if they had any). The resources favored by the majority of the seven teachers were subsequently selected and included as primary analogies in the texts. In cases of two equally favored resources, both were used.

The Certainty section consisted of 433 words structured in six paragraphs, the Simplicity section consisted of 544 words structured in seven paragraphs. The Source section consisted of 420 words structured in five paragraphs and the Justification section consisted of 575 words structured in eight paragraphs. The average number of words per sentence was again 23 (see Appendix G for all four sections of the analogy text).

Text Comprehension

In this study students were asked to read and recall texts for two purposes: (a) to examine their Text Comprehension Ability before the beginning of the study, and (b) to examine their Comprehension Performance (comprehension of the intervention texts).

Recall Scoring. A three-step procedure was followed for the scoring of students' recalls: (a) All texts (one expository text used to examine Text Comprehension before the beginning of the study and the three intervention texts) were parsed into clauses by two independent raters. Interater reliability on text parsing indicated agreement on 92% of parsed texts (K = 0.84, p = < .01). Disagreements were resolved in conference (b) all students' recalls were typed and 15% of the student recalls were parsed into clauses by two independent raters. Interater reliability on parsing indicated agreement on 94% of parsed recalls (K = .85, p < .01). Disagreements were discussed and resolved and the second rater parsed all remaining recalls. (c) 15 % of the parsed students' recalls were scored by two independent raters. Interrater reliability on scoring indicated 91% agreement of scored recalls (K = .83, p < .01). Disagreements were resolved in conference and the second rater scored all remaining recalls.

Recalls were scored on the basis of gist. Recall idea units that represented verbatim recall or valid paraphrases of text idea units were scored as correct. Recall idea units that were valid but could not be matched to the text were scored as valid inferences. Incorrect idea units and invalid inferences were scored as distortions. A valid inference could represent a connection between sentences, elaboration or prediction originating from specific text ideas (Diakidoy et al., 2011). Table 14 presents a text idea unit from the Certainty section of the baseline text ('Different theories may change'), an example of a verbatim recall, a paraphrase recall and inference recall of this idea unit. The examples are derived from students' recalls.

Table 14

Examples of recall types of the text idea unit 'Different theories may change'

Recall Type	Examples from students' recalls
Verbatim Recall	Theories change
Paraphrase Recall	Theories do not remain the same
Valid Inference	If a new theory explains the results of an experiment better than another theory, then theory changes

Text Comprehension-Recall Score (TC-RS). Before the beginning of the study, students were asked to read and recall a short expository text titled 'A journey to Antarctica' (271 words long, structured in six paragraphs, 18 sentences, 15 words in each sentence on average) about a journey of a group of explorers from Greece who visited Antarctica and talked about their experiences. The scoring of students' recalls was performed using the three-step scoring procedure outlined above, although only recall units that were identified as verbatim recalls or valid paraphrases were used for the purposes of this measure. Students' recall score of the 'Journey to Antarctica' text (Text Comprehension-Recall Score) represented an index of students' Text Comprehension Ability before the beginning of the study.

Teacher-Rated Text Comprehension Ability (TRAT). A second index of students' Text Comprehension Ability before the beginning of the study was also used. Teachers of participating classes who taught the majority of curriculum subjects in their class, were required at the beginning of the study to grade their students' text comprehension ability using the grades A,B,C,D and E. A was given to students with high comprehension ability, B to students with very good comprehension ability, C to students with average comprehension ability, D to students with low comprehension ability and E to struggling readers.

Text Comprehension Performance. The extent to which experimental texts were comprehended was measured in two ways, with a Main Idea Recall task and a Free Recall task that followed the reading of each text. In terms of the Main Idea Recall task students were required to write in the provided space the main idea of the text section they just read in one sentence. If students had not provided a main idea in the appropriate space or if they had written an incorrect main idea, their responses were scored with a zero. A score of one was given to responses that referred to a minor detail of the text. A score of two was given to correct main ideas and a score of three was given to elaborated main idea responses. It has been previously mentioned that three sixth grade teachers where asked to provide the main idea of each text section of the three Text Types. The extent to which a main idea response could be considered correct was decided upon comparison with the teachers' main idea responses. A number (15%) of students' responses to the Main Idea Recall task were scored by two independent raters. Interrater reliability indicated agreement on 82% of scored main idea responses ($K = .65$, $p < .01$). Disagreements were resolved in conference and another 15% of students' responses was again scored by the same independent raters. Interater-reliability improved ($K = .83$, $p< .01$) and agreement reached 92 % of the scored responses. All remaining main idea responses were scored by the second rater. Students' main idea scores on each text section were summed and yielded a total score (Text Main Idea Recall).

The Free Recall task that followed the Main Idea Recall task was also scored using the three-step scoring procedure outlined above. It should be noted however that in order to avoid any confounding in the scores of the students of the three groups and enable comparisons across those scores, any clauses in students' recalls who read the refutation or the analogy text and that referred to the extra information added in these two texts as a function of their type (i.e. refutations and analogies) were not considered for the calculation of their total scores.

Recall idea units that represented verbatim recall or valid paraphrases of text idea units were considered for the calculation of an overall recall score. The overall recall scores of the four text sections were summed and yielded the Total Overall Recall Score which was used for the calculation of the Mean Overall Recall Score (MORS) across the four text sections.

Moreover, recall idea units that were scored as valid inferences for each text section were again totaled in order to provide a Total Number of Valid Inferences score (TNVI) for all four text sections. Incorrect idea units that were scored as invalid inferences or distortions were not considered for any further analysis as the information they provided was considered unrelated to the purposes of this study.

Procedure

The study was completed in four sessions. Before the beginning of the study (session 1, 40 minutes) all students read the expository text “A journey to Antarctica” and recalled the text. On the same session teachers were asked to provide grades on their students’ text comprehension ability. At the beginning of the study (session 2, 80 minutes) all students completed the Personal Epistemology in Science Questionnaire (PESQ), the Personal Interest in Science Questionnaire (PISQ) and the Prior Knowledge in Science Test (PKST). About two weeks later (session 3, 80 minutes), students read the intervention texts. All three text types were administered in all participating classes and texts were administered to students in random order. A subgroup of students of each class read the baseline texts, a second subgroup read the refutation texts and a third subgroup read the analogy texts. Each student received a booklet containing four text sections (corresponding to the four dimensions). The booklet also included the filler task (a mathematics magic square), the Situation Interest measure, the Main Idea Recall task and the Free Recall task. The filler task, the Situation Interest measure, the Main Idea Recall task and the Free Recall task appeared at the end of each text section (four times in total). To counterbalance order effects students read about the four dimensions in different order (each text was presented in four versions in each text type). Immediately after completion of reading of each one of the four text sections, students responded to the situation interest measure and completed the magic square. They were subsequently asked to write the main idea and lastly to free recall the text in the provided space. The following day (session 4, 40 minutes) students completed again the PESQ.

CHAPTER 4

Results

The study concerned three research questions. The main research question was twofold. The first part involved a comparison of two text-based interventions (refutation text and analogy text) that derived from two corresponding theoretical frameworks in terms of their effectiveness in promoting sixth grade students' personal epistemology advancement in science. The second part of this question focused on the impact of text comprehension, interest and prior knowledgee in science on personal epistemology advancement. This question was examined with the performance of a repeated measures analysis of covariance (RM-ANCOVA). The second research question concerned the impact of individual differences variables (interest and prior knowledge) on text comprehension and it was examined with the use of multivariate analysis of covariance (MANCOVA). The third question was also twofold. In the first part it involved issues of measurement of personal epistemology in young elementary school students, while for the second part it involved an examination of the extent to which the hypothesized multidimensional structure was manifested in this younger age group. This chapter will present analyses related to the first two questions, as results related to the third question were presented in Chapter 3.

Preliminary Analyses

Preliminary analyses indicated that the two dependent variables (Explicit Personal Epistemology and Implicit Personal Epistemology) were normally distributed (skewness and kurtosis <1). Table 15 presents correlations between the two dependent measures that correspond to the two parts of the Personal Epistemology in Science Questionnaire (PESQ). Part A (dichotomous items) examined Personal Epistemology explicitly, while Part B (scenarios) examined the same construct implicitly. To facilitate the presentation of findings, Explicit Personal Epistemology at the Pretest will be labelled as PESQ-Expl-Pretest and Explicit Personal Epistemology at the Posttest will be labeled as PESQ-Expl-Posttest. Implicit Personal Epistemology at the Pretest will correspond to PESQ-Impl-Pretest and Implicit Personal epistemology at the Posttest will correspond to PESQ-Impl-Posttest. It should be noted that due to preliminary Rasch analyses that established the reliability of the Personal Epistemology in Science Questionnaire (PESQ), which was presented in Chapter 3, it was considered appropriate to maintain Rasch scores in all following statistical analyses.

Table 15 indicates that significant positive correlations were observed between the scores of each of the two measures at the Pretest and the Posttest. However, the correlations were also significant between the pretest scores of Explicit and Implicit Personal Epistemology (r=.42**) and the two posttest scores of Explicit and Implicit Personal Epistemology (r=.56**). These correlations indicate possible common ground between these two different facets of personal epistemology.

Table 15

Correlations between Explicit and Implicit Personal Epistemology (Part A and Part B of PESQ) at Pretest and Posttest

	PESQ-Expl-Post	PESQ-Impl-Pre	PESQ-Impl-Post
PESQ-Expl-Pre	.60**	.42**	.36**
PESQ-Expl-Post		.53**	.56**
PESQ-Impl-Pre			.48**

**p < .01.

Table 16 outlines the correlations of Explicit Personal Epistemology and Implicit Personal Epistemology at both the Pretest and the Posttest with Personal Interest in Science (PIS), Situational Interest (SIT), Prior Knowledge in Science (PKS), Text Comprehension-Recall Score on Expository Text (TC-RC) and Teacher-Rated Text Comprehension Ability (TRAT). Table 16 also presents correlations of Explicit Personal Epistemology and Implicit Personal Epistemology with the three measures of the comprehension of the experimental texts: Mean Overall Recall Score (MORS), Total Number of Valid Inferences (TNVI) and Text Main Idea Recall (TMI). All variables presented below, with the exception of TNVI, were normally distributed (skewness and kurtosis<1). TNVI was positively skewed (skewness =1.58) and thus the squared root transformation of TNVI was used in all subsequent analyses.

As shown in Table 16, Explicit Personal Epistemology, at both the Pretest and the Posttest, correlated significantly with all the other variables in the study, except with Personal Interest in Science (PIS), Situational Interest (SIT) and Mean Overall Recall Score (MORS). Likewise, Implicit Personal Epistemology, at the Pretest correlated significantly with all the other variables except Personal Interest in Science (PIS), Situational Interest (SIT) and Mean Overall Recall Score (MORS). Implicit Personal Epistemology at the Posttest correlated with all the variables with the only exception of Situational Interest (SIT) and Mean Overall Recall Score (MORS). Table 2 shows also that Personal Interest in Science (PIS) correlated significantly only with Text Comprehension-Recall Score (TC-RS), while Prior Knowledge in Science (PKS) correlated significantly with Text Comprehension-Recall Score (TC-RS), Teacher-Rated Text Comprehension Ability (TRAT), Total Number of Valid Inferences (TNVI) and also with Text Main Idea Recall (TMI). The two indices of Text Comprehension Ability (TC-RS and TRAT) correlated significantly with each other, while both variables correlated significantly with the three variables that related to the comprehension of the experimental texts (MORS, TNVI and TMI). All three comprehension variables were also significantly correlated with each other.

Table 16

Correlations between Explicit Personal Epistemology (Part A of PESQ) with Interest in Science, Prior Knowledge in Science and Text Comprehension

	PIS	PKS	TC-RS	TRAT	SIT	MORS	TNVI	TMI
PESQ-Expl-Pre	.02	.41**	.25**	.55**	.08	.09	.38**	.43**
PESQ-Expl-Post	.11	.35**	.33**	.59**	.10	.10	.34**	.54**
PESQ-Impl-Pre	.08	.28**	.21**	.41**	.02	.10	.24**	.35**
PESQ-Impl-Post	.20*	.25**	.31**	.33**	.10	.15	.33**	.34**
PIS		.05	.24**	.12	.12	.05	.08	.04
PKS			.23**	.36**	-.03	.02	.15*	.41**
TC-RS				.44**	.06	.17*	.23**	.23**
TRAT					-.07	.18*	.31**	.48**
SIT						.04	.13	-.07
MORS							.15*	.21**
TNVI								.31**
Means	31.30	35.53	.15	4.14	5.04	.07	1.62	5.35
SD	8.40	8.40	.09	0.86	2.12	.05	0.84	1.62

**p* < .05. ***p* < .01

A series of one-way analyses of variance (ANOVA) were performed to examine the extent to which the three text groups (baseline, refutation and analogy) were comparable in terms of Interest and Prior Knowledge in Science, Text Comprehension Ability (Text Comprehension-Recall Score and Teacher-Rated Text Comprehension Ability) and level of Explicit Personal Epistemology at the beginning of the study. Table 17 indicates that all three groups were comparable in all the variables included in the analyses, as indicated by the non-significant F-tests.

Table 17

Mean Scores in Personal Epistemology at the Pretest, Interest, Prior Knowledge and Text Comprehension Ability

	Baseline	Refutation	Analogy	F	Sig
PESQ-Expl-Pre [a]	0.93 (0.69)	1.05 (0.65)	1.02 (0.67)	0.59	.557
PIS	31.80 (8.67)	31.56 (8.11)	30.60 (8.48)	0.33	.717
PKS	36.11 (7.92)	36.04 (9.16)	35.53 (8.40)	0.68	.506
TC-RS	0.14 (0.09)	0.15 (0.10)	0.15 (0.09)	0.09	.917
TRAT	4.12 (0.80)	4.22 (0.80)	4.08 (0.86)	0.42	.658

Note. Standard deviations are shown in parentheses. Data collection of the variables presented above was conducted in different data collection time points and there were thus differences in sample size: PESQ-Exp-Pre and TRAT (N=175), PIS (N=171), PKS (N=172), TC-RS (N=164).

[a] *Means and standard deviations are presented in Rasch standardized values.*

Personal Epistemology Advancement

Explicit Personal Epistemology

The primary purpose of this study was to examine the effectiveness of short-term instructional interventions in promoting personal epistemology advancement. The results of an overall paired t-test indicated that students had higher performance on Explicit Personal Epistemology at the Posttest (M = 1.13, SD = 0.78) compared to their performance on Explicit Personal Epistemology at the Pretest (M = 1.00, SD = 0.67), t (174) = -2.60, p = .01, *Cohen's d* = 0.18. The significant difference in students' scores on Explicit Personal Epistemology indicated that reading about epistemology in science was generally effective in promoting students' personal epistemology. It was hypothesized however, that reading the two experimental texts, refutation and analogy, would be more effective in advancing personal epistemology compared to reading the baseline text.

Advancement of personal epistemology in science as a result of reading about epistemology in science was assumed to represent a special case of the Model of Domain Learning (MDL); (Alexander, Jetton, & Kulikowich, 1995). According to MDL, interest, prior knowledge and text comprehension interact and impact domain learning. Therefore, in order to examine the impact of the variables Personal Interest in Science, Prior Knowledge in Science and Text Comprehension on Explicit Personal Epistemology at the Pretest and the Posttest, two multiple regression analyses were performed. It should be noted that in this study, two types of interest were examined: Personal Interest and Situational Interest. Personal Interest represents a trait-like characteristic, while Situational Interest is bound to a particular learning activity. Consequently, Personal Interest was included in the first multiple regression analysis that involved Explicit Personal Epistemology at the Pretest (before reading), while in the second multiple regression analysis that involved Explicit Personal Epistemology at the Posttest (after reading), both types of interest were considered.

Moreover, Text Comprehension was examined at two levels: as Text Comprehension Ability and as Text Comprehension Performance. Text Comprehension Ability was measured on the basis of the Overall Recall Score of students in an expository text (TC-RS) and also on the basis of class teachers' ratings of their students' text comprehension ability (TRAT). Text Comprehension Performance is represented by students' Mean Overall Recall Score (MORS), their Total Number of Valid Inferences (TNVI) and their Text Main Idea Recall score (TMI). As a result, in the first regression analysis that involved Explicit Personal Epistemology at the

Pretest, only the two variables that corresponded to Text Comprehension Ability (TC-RS and TRAT) were considered, while in the second regression analysis that involved Explicit Personal Epistemology at the Posttest (after reading), the impact of the three variables that represented Text Comprehension Performance (MORS, TNVI and TMI) was also examined.

Predictors of Explicit Personal Epistemology at the Pretest. To examine the contribution of Interest, Prior knowledge and Text Comprehension Ability in the variance observed at the level of Explicit Personal Epistemology at the Pretest (PESQ-Expl-Pre) a multiple regression analysis was performed with all of the following variables entered in one step: Personal Interest in Science (PIS), Prior Knowledge in Science (PKS), Text Comprehension-Recall Score (TC-RS) and Teacher-Rated Text Comprehension Ability. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity and collinearity. Results indicated that the variables entered in the analysis explained 34% of the variance in the initial level of explicit personal epistemology (Adj. Model R^2 = .34). TRAT ($\beta = 0.47$, $t = 6.24$, $p = .000$) and PKS ($\beta = 0.25$, $t = 3.59$, $p = .000$) emerged as the only significant predictors of Explicit Personal Epistemology at the Pretest, with highest standardized beta values and associated significant t-tests.

Predictors of Explicit Personal Epistemology at the Posttest. The next step in the process of delineating the process of personal epistemology advancement within the context of this study was to understand how the level of Explicit Personal Epistemology at the Pretest, along with Interest, Prior Knowledge and Text Comprehension (Ability and Performance) influenced the variance observed in the level of Explicit Personal Epistemology at the Posttest. A multiple regression analysis was conducted with Explicit Personal Epistemology at the Posttest (PESQ-Expl-Post) as the dependent variable and with Explicit Personal Epistemology at the Pretest (PESQ-Expl-Pre), Personal Interest in Science (PIS), Prior Knowledge in Science (PKS), Text Comprehension-Recall Score (TC-RS), Teacher-Rated Text Comprehension Ability (TRAT), Situational Interest (SIT), Mean Overall Recall Score (MORS), Total Number of Valid Inferences (TNVI) and Text Main Idea Recall (TMI) as predictors, entered all in one step. Again, preliminary analyses were conducted to verify that the assumptions of normality, linearity and collinearity were not violated. Results indicated that the model explained 50% of the variance observed in the dependent variable (Adj. Model R^2 = .50). Explicit Personal Epistemology at the Pretest ($\beta = .30$, $t = 4.06$, $p = .000$), Text Main Idea Recall ($\beta = .28$, $t = 4.02$, $p = .000$) and Teacher-Rated Text Comprehension Ability

($\beta = .26$, $t = 3.36$, $p = .001$) emerged as the only significant predictors of Explicit Personal Epistemology at the Posttest.

Explicit Personal Epistemology Advancement. On the basis of the results of the two multiple regression analyses presented above, a repeated measures analysis of covariance (RM-ANCOVA) was performed in order to examine the effects of the independent variable (Text Type), the variables that emerged as significant predictors of Explicit Personal Epistemology at the Posttest (Teacher-Rated Text Comprehension Ability, Text Main Idea Recall) and their possible interactions in personal epistemology advancement. Time with two levels (PESQ-Expl-Pre and PESQ-Expl-Post) was used as the within subjects factor, Text Type was used as the between subjects factor, while Teacher-Rated Text Comprehension Ability (TRAT) and Text Main Idea Recall (TMI) were entered as covariates. The results indicated a significant Time x Text interaction, $F\,(2, 165) = 4.41$, $p = .014$, $\eta^2 = 0.05$, a Time x Text x TRAT interaction, $F(2,165) = 11.51$, $p = .000$, $\eta^2 = 0.12$ and a Time x Text Type x TMI interaction, $F(2,165) = 3.94$, $p = .021$, $\eta^2 = 0.05$. The mean scores of each Text Group at the Pretest and the Posttest are presented in Table 18 in order to facilitate interpretation of the Time x Text interaction.

Table 18

Means of Explicit Personal Epistemology at the Pretest and the Posttest for each Text Group

	n	Pretest	Posttest	Cohen's *d*
Baseline	57	0.93 (0.69)	1.05 (0.69)	0.17
Refutation	58	1.06 (0.65)	1.18 (0.70)	0.18
Analogy	60	1.02 (0.66)	1.17 (0.93)	0.19

Note. Standard deviations are shown in parentheses.

Table 18 indicates that although all three Text groups improved their Explicit Personal Epistemology at the Posttest, the Analogy group showed the largest gains. Despite that the difference in scores observed in the Analogy group from the Pretest to the Posttest were the largest compared to the other two groups, the observed change was rather modest as indicated by the small effect size. The mean scores of the Refutation group remained the highest at both testing times. The gains observed in the Baseline and the Refutation groups were the same. The Time x Text interaction is also illustrated in Figure 9.

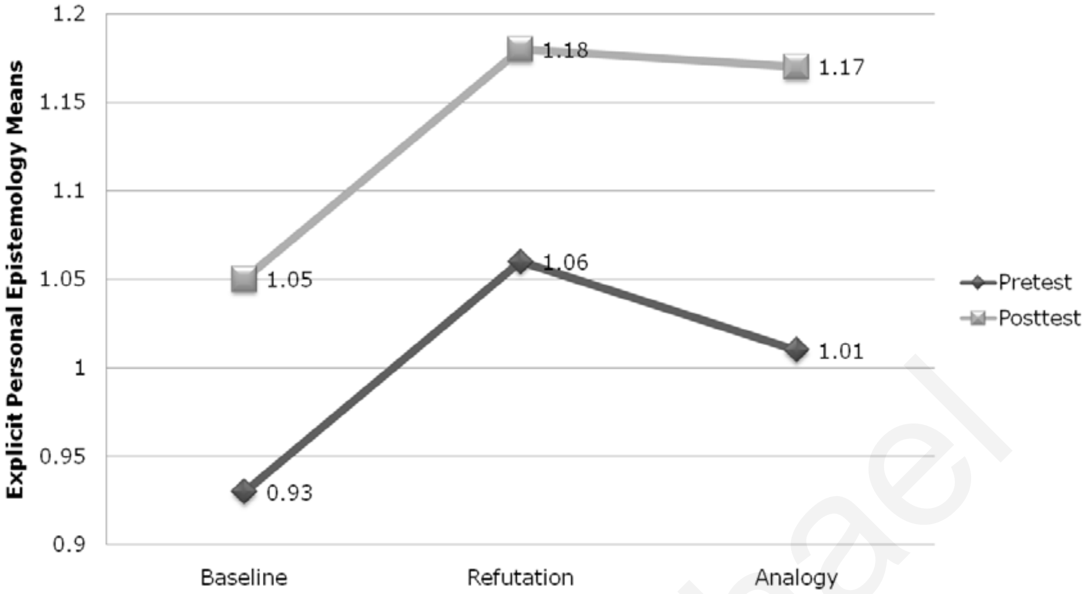

Figure 9. Mean scores of Explicit Personal Epistemology across the two testing periods, showing the interaction between Time and Text Type.

To explicate and interpret the Time x Text x TRAT interaction the means on Explicit Personal Epistemology at the Pretest and the Posttest are presented in Table 19 as a function of Text group and Teacher-Rated Text Comprehension Ability.

Table 19

Means of Explicit Personal Epistemology at the Pretest and the Posttest as a function of Teacher-Rated Text Comprehension Ability and Text Group

	Baseline		Refutation		Analogy	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
TRAT						
2[a]	-		0.19(0.37)	0.27(0.29)	0.20(0.18)	-0.25(0.53)
3	0.46(0.44)	0.73(0.68)	0.48(0.38)	0.64(0.28)	0.51(0.73)	0.35(0.38)
4	0.81(0.62)	1.00(0.71)	0.99(0.63)	1.07(0.70)	1.01(0.48)	0.96(0.61)
5	1.36(0.67)	1.32(0.59)	1.38(0.57)	1.52(0.63)	1.40(0.49)	1.93(0.64)

Note. Standard deviations are shown in parentheses.

[a] There were no students with low comprehension ability (TRAT=2) in the Baseline group, while there were two students in the Refutation group and four in the Analogy group.

Table 19 shows that the Refutation group was the only text group where students of differing comprehension ability consistently manifested gains in personal epistemology after reading the experimental text. The number of students with medium, very good and high comprehension ability was overall comparable across the three text groups. In the Baseline group, after reading, the Explicit Personal Epistemology mean scores of students with medium (TRAT=3) and very good (TRAT=4) comprehension ability increased, while there was a slight decrease in the mean scores of students with high comprehension ability (TRAT=5). A very different pattern emerged in the Analogy group. After reading the experimental text, the Explicit Personal Epistemology mean scores of students with low (TRAT=2), medium (TRAT=3) and very good (TRAT=4) comprehension ability decreased, while the scores of students with high comprehension ability (TRAT=5) increased. The gains of high comprehenders in the Analogy group were the largest compared to any gains in the two other groups. Paired samples t-tests were subsequently conducted to examine the significance of the observed changes in students' Explicit Personal Epistemology mean scores in the three groups for each text comprehension ability rating. Results indicated that indeed the increase in the mean scores of students with high comprehension ability in the Analogy group was significant, $t(25) = -4.69$, $p = .000$, Cohen's $d = 0.93$. Furthermore, the increase in the mean scores of students with average comprehension ability in the Refutation group was also significant, $t(6) = -2.70$, $p = .036$, Cohen's $d = 0.48$, although it must be noted that the small number of students in this group precludes confidence in this finding. Figure 10 illustrates the changes in the mean scores of Explicit Personal Epistemology of the students in the three groups for each rating of text comprehension ability.

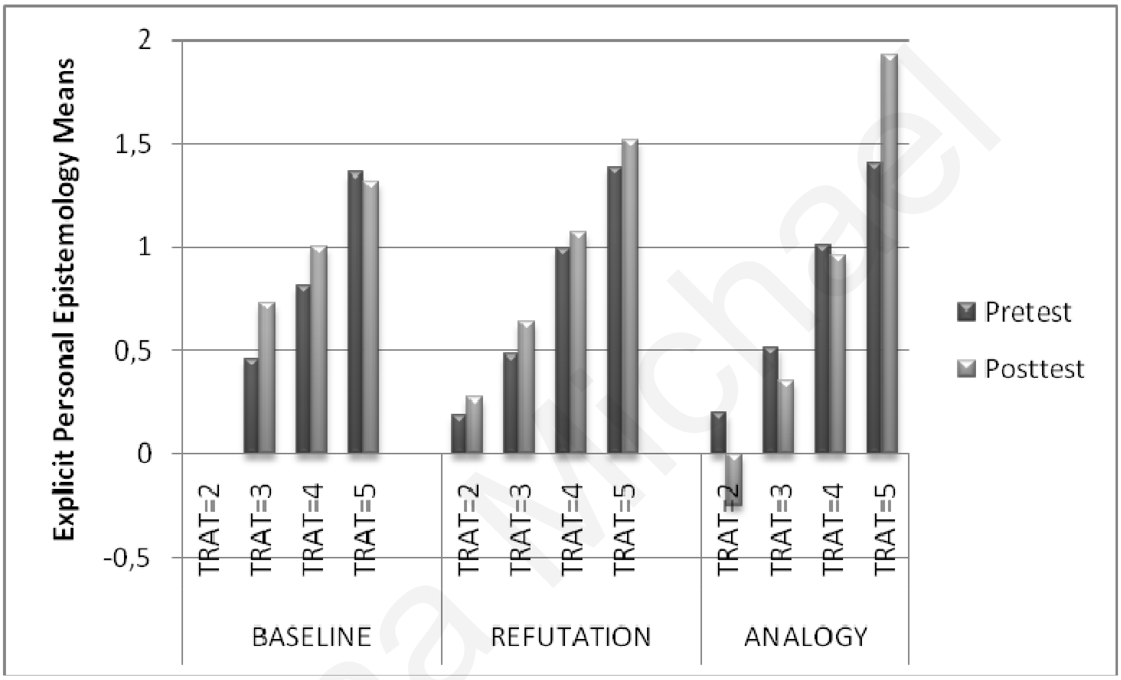

Figure 10. Mean scores of Explicit Personal Epistemology across the two testing periods showing the interaction of Time, Text Type and Teacher-Rated Text Comprehension Ability.

To explicate the Time x Text x TMI interaction the variable Text Main Idea Recall (TMI) was dichotomized at the median (*Mdn* = 5), in order to create two groups, a group of students with higher Text Main Idea Recall scores (TMI > 5) and a group of students with lower Total Main Idea scores (TMI ≤ 5) scores. The effects of the dichotomized Text Main Idea Recall variable were subsequently examined within each of the three text groups. Table 20 presents the mean scores of Explicit Personal Epistemology as a function of the interaction of Time with Text Main Idea Recall and Text Type.

Table 20

Means of Explicit Personal Epistemology at the Pretest and the Posttest as a function of the interaction of Text Type with Text Main Idea Recall

	n	Pre	Post	t	Sig
TMI ≤ 5					
Baseline	35	0.75(0.66)	0.83(0.67)	-0.70	.489
Refutation	29	0.86(0.61)	0.82(0.47)	0.35	.732
Analogy	32	0.76(0.67)	0.85(1.01)	-6.45	.524
TMI > 5					
Baseline	22	1.21(0.66)	1.40(0.58)	-1.21	.239
Refutation	29	1.27(0.64)	1.52(0.73)	-2.49	.019
Analogy	28	1.31(0.53)	1.53(0.69)	-2.07	.049

Note. Standard deviations are shown in parentheses.

As it can be seen in Table 20, students with lower Total Main Idea scores and who read either the Baseline or the Analogy texts improved their Explicit Personal Epistemology scores from Pretest to Posttest. Students with lower Total Main Idea scores and who read the Refutation text decreased their Explicit Personal Epistemology scores from Pretest to Posttest. Nevertheless, none of these differences reached statistical significance. All three text groups raised their scores within the higher TMI group. However, the most substantial and statistically significant gains were observed in the Refutation text group (Cohen's d = 0.36). Gains in the Analogy text group reached marginal significance (Cohen's d = 0.35), while the gains observed in the baseline group were not significant (Cohen's d = 0.30).

Analysis so far indicates that from the three variables originally included in the design of the study, Interest in Science (Personal and Situational), Prior Knowledge and Text Comprehension (Ability and Performance), the latter had the largest impact on the effects of the text-based interventions. It was important thus, to understand which variables influenced the comprehension of the experimental texts.

Impact of Prior Knowledge and Text Comprehension Ability on Comprehension of Experimental Texts[1]

Mean Overall Recall Score (MORS), Total Number of Valid Inferences (TNVI) and Text Main Idea Recall (TMI) were the three variables that represented measures of Text Comprehension Performance (comprehension of the experimental texts). A multivariate analysis of covariance (MANCOVA) was performed, with these three comprehension variables as dependent variables, Text as the independent variable and Personal Epistemology at the Pretest (PESQ-Expl-Pre), Prior Knowledge in Science (PKS) and Teacher-Rated Comprehension Ability (TRAT) as covariates.. The analysis did not yield any significant multivariate effects, while there was only one significant between subjects Text x PKS interaction effect on TNVI, $F(2,158) = 4.56$, $p = .012$, $\eta^2 = 0.06$. To investigate further the effect of this interaction on students' text inferential outcomes, PKS was dichotomized on the basis of the median to create two equal-sized groups, with lower (PKS $\leq$ 36) and higher (PKS > 36) PKS. Table 21 presents means of the Total Number of Valid Inferences variable for students with lower Prior Knowledge and for students with higher Prior Knowledge. As it can be seen in this table, the differences between the lower and the higher Prior Knowledge groups were larger for the analogy group, indicating that students who read the analogy text generated more inferences when they had high Prior Knowledge. The differences between students with lower and higher Prior Knowledge students within the analogy text group approached significance, $t(57) = -1.91$, $p = .061$, while the differences between the lower and the higher Prior Knowledge students within the baseline and the refutation texts were not significant, $p > .05$. Figure 11 illustrates students' Total Number of Valid Inferences as a function of the interaction of Prior Knowledge in Science with Text Type.

[1] It should be noted that Interest (Personal and Situational) was not considered for this analysis due to lack of correlation with any of the comprehension-related variables.

Table 21

Means of Total Number of Valid Inferences as a function of the Interaction of Text Type with Prior Knowledge

	Baseline	Refutation	Analogy
Prior Knowledge			
Lower	1.52 (1.06)	1.63 (0.90)	1.42 (0.78)
Higher	1.71 (0.63)	1.68 (0.92)	1.83 (0.83)
Cohen's *d*	0.22	0.00	0.51

Note. Standard deviations are shown in parentheses.

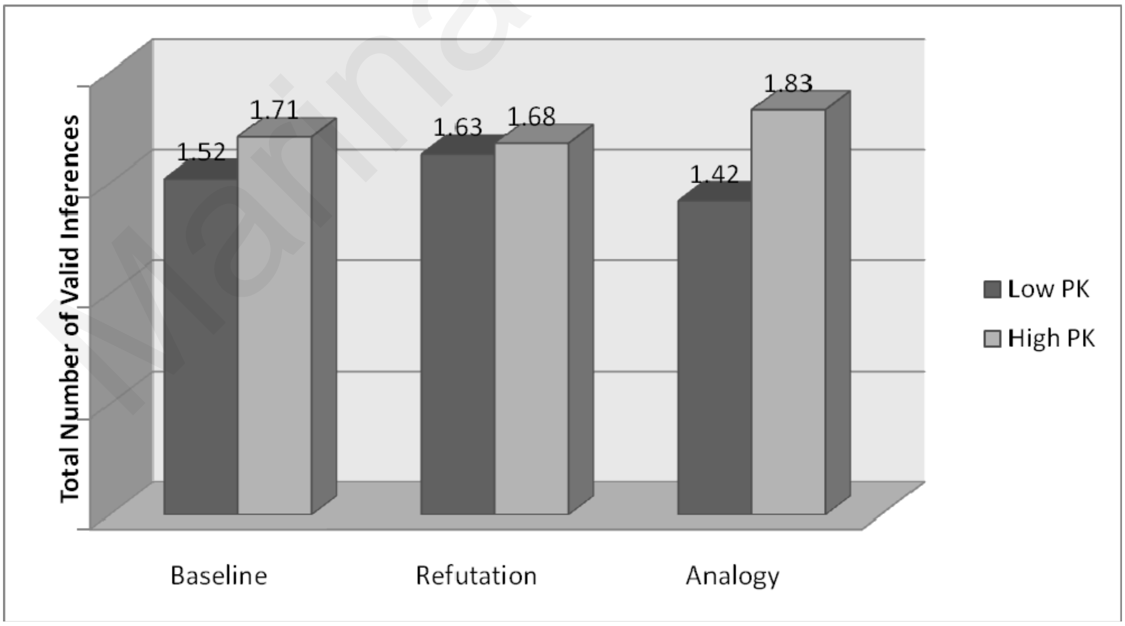

Figure 11. Total Number of Valid Inferences as a function of the interaction of Prior Knowledge in Science with Text Type

Implicit Personal Epistemology

A paired-samples t-test indicated that overall, students' mean scores on Implicit Personal Epistemology did not significantly change from the Pretest (M = 0.70, SD = 0.98) to the Posttest (M = 0.64, SD = 1.22), $t(174)$ = 0.67, p = .504. One-way analysis of variance (ANOVA) with Text as the independent variable indicated that the three groups were comparable in terms of their mean scores on Implicit Personal Epistemology at the Pretest. The mean scores of students in the three groups however, did not significantly change from the Pretest to the Posttest (see Table 22). Paired-samples t-tests within each text group indicated that any differences observed within each group were not significant ($p < .05$).

Table 22

Means of Implicit Personal Epistemology at the Pretest and the Posttest for each Text Group

	Baseline n=57	Refutation n=58	Analogy n=60	F	Sig
PESQ-Impl-Pre	0.62 (0.86)	0.63 (0.93)	0.85 (1.12)	1.02	.363
PESQ-Impl-Post	0.62 (1.07)	0.58 (1.24)	0.74 (1.35)	0.27	.764
Cohen's d	0.00 0.04	0.08			

Note. Standard deviations are shown in parentheses.

Predictors of Implicit Personal Epistemology at the Pretest. To enhance understanding of which variables reliably predicted Implicit Personal epistemology at the Pretest a multiple regression analysis was performed with Implicit Personal Epistemology as the dependent variable and the variables Personal Interest in Science (PIS), Prior Knowledge in Science (PKS), Text Comprehension-Recall Score (TC-RS) and Teacher-Rated Text Comprehension Ability (TRAT) all entered simultaneously. Preliminary analyses were conducted to ensure that the assumptions of normality, linearity and collinearity were not violated. The resulting model explained 17% of the variance observed in the dependent variable (Adj. Model R^2 = .17) with only TRAT emerging as a reliable predictor of Implicit Personal Epistemology at the Pretest (β = 0.35, t = 4.20, p = .000).

Predictors of Implicit Personal Epistemology at the Posttest. Following the examination of the predictors of Implicit Personal Epistemology at the Pretest, a second multiple regression analysis was conducted in order to specify reliable predictors of Implicit Personal Epistemology at the Posttest. PESQ-Impl-Post was used as the dependent variable and the following variables were all entered in one step: Implicit Personal Epistemology at the Pretest (PESQ-Impl-Pre), Personal Interest in Science (PIS), Prior Knolwedge in Science (PKS), Text Comprehension-Recall Score (TC-RS), Teacher-Rated Text Comprehension Ability (TRAT), Situational Interest (SIT), Mean Overall Recall Score (MORS), Total Number of Valid Inferences (TNVI) and Text Main Idea Recall (TMI). The resulting model predicted 30% of the variance in Implicit Personal Epistemology at the Posttest (Adj. Model R^2 = 0.30) with Implicit Personal Epistemology at the Pretest emerging as the most significant predictor (β = 0.35, t = 4.62, p = .000). TNVI also emerged as a predictor of Implicit Personal Epistemology at the Posttest (β = 0.15, t = 2.11, p = .036).

Implicit Personal Epistemology Advancement. On the basis of the results of the two multiple regression analyses presented above, a repeated measures analysis of covariance (RM-ANVOVA) was conducted in order to examine the level of change observed in Implicit Personal Epistemology. Time with two levels (PESQ-Impl-Pre and PESQ-Impl-Post) was used as the within subjects factors, Text Type was entered as the between subjects factor, while Total Number of Valid Inferences (TNVI) was entered as a covariate. There was only one significant main effect of Time, F(1,169) = 4.07, p=.045, η^2 = .02 and a marginally significant multivariate Time x TNVI interaction effect, F(1,169) = 3.75, p = .054, η^2 = .02. There was also one significant between subjects effect of TNVI F(1,169) = 23.64, p = .000, η^2 = .12. The main effect of Total Number of Valid Inferences (TNVI) was investigated further by dichotomizing this variable at the median (*Mdn* = 1.4[2]) in order to create two distinct groups, one group with lower Total Number of Valid Inferences score (TNVI $\leq$ 1.4) and one group with higher Total Number of Valid Inferences score (TNVI $>$ 1.4). The means of the lower TNVI group and the higher TNVI group were M = 0.32, SD = 1.06 and M = 0.98, SD = 1.29, respectively. An independent samples t-test was performed to compare the means of the two groups in respect to their Implicit Personal Epistemology scores at the Posttest, indicating that the differences between the two groups, were highly significant, t(173) = -3.71, p = . 000, *Cohen's d* = 0.56.

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[2] Readers are reminded that the squared root transformation of the TNVI variable was used in all analyses.

The marginally significant multivariate interaction effect of Time x TNVI was also investigated. The means on Implicit Personal Epistemology were examined as a function of the interaction of Time with the Total Number of Valid Inferences. As it can be seen from Table 23 the mean scores of students in the lower TNVI group decreased from the Pretest to the Posttest, while the mean scores of students in the higher TNVI group increased from the Pretest to the Posttest. The differences, however, were not statistically significant ($p > .05$).

Table 23

Implicit Personal Epistemology as a function of the interaction of Time with Total Number of Valid Inferences

	Pre		Post		t	Sig
Total Number of Valid Inferences						
Lower	0.51	(1.06)	0.32	(1.06)	1.71	.091
Higher	0.90	(0.84)	0.98	(1.29)	-0.58	.562

Note. Standard deviations are shown in parentheses.

In order to decipher the pattern of change in scores between the three text groups the means of the two TNVI groups were examined as a function of Time and Text Type. As it can be seen in Table 24 the mean scores of students in the Lower Total Number of Valid Inferences group in all the three text groups decreased from the Pretest to the Posttest, whilst the mean scores of students in the higher Total Number of Valid Inferences group increased from the Pretest to the Posttest. Independent samples t-tests were conducted to compare the mean scores of Implicit Personal Epistemology at the Posttest between students in the lower and students in the higher TNVI groups for each of the three text groups. Results indicated that differences between the scores of students in the lower and the higher TNVI groups were significant for the Baseline Text group and the Analogy Text group, $t(55) = -3.54$, $p = .001$, Cohen's $d = 0.95$ and $t(58) = -2.15$, $p = .037$, Cohen's $d = 0.55$ respectively. The corresponding differences for the Refutation text group were not significant ($p > .05$). Figure

12 illustrates the differences in Posttest Implicit Personal Epistemology between the two Total Number of Valid Inferences groups for each Text Type.

Table 24

Implicit Personal Epistemology as a function of an interaction of Time with Text Type and Total Number of Valid Inferences

	Total Number of Valid Inferences			
	Lower		Higher	
	Pre	Post	Pre	Post
Baseline	0.28(0.86)	0.13(0.68)	0.93(0.76)	1.05(1.18)
Refutation	0.56(0.96)	0.39(1.06)	0.70(0.90)	0.77(1.39)
Analogy	0.64(1.28)	0.41(1.31)	1.10(0.84)	1.14(1.32)

Note. Standard deviations are shown in parentheses.

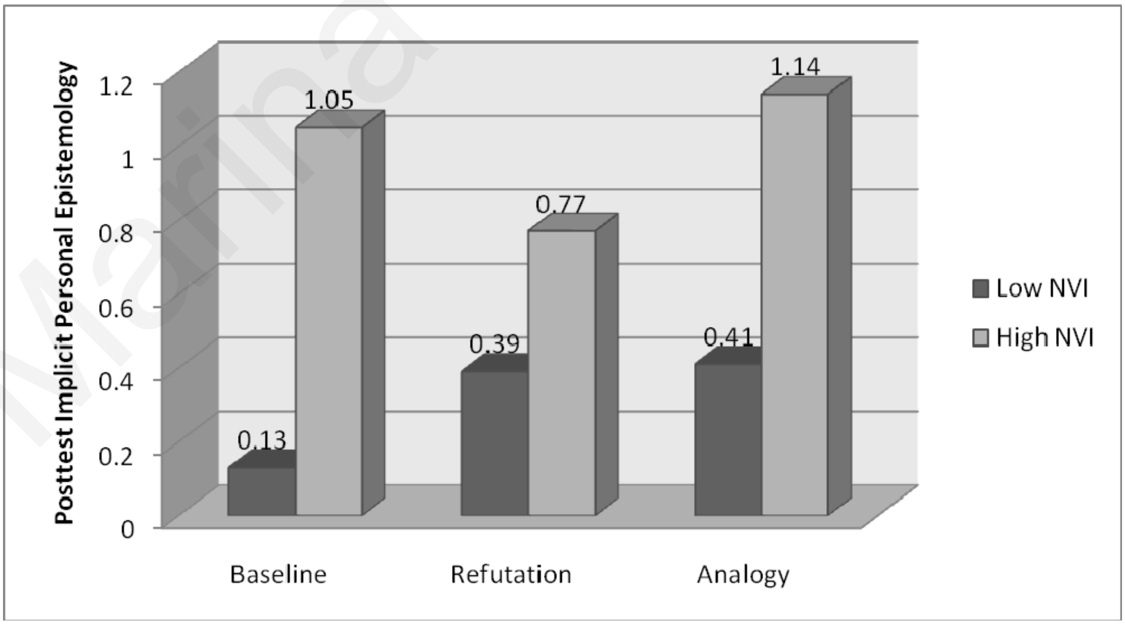

Figure 12. Posttest Implicit Personal Epistemology as a function of an interaction of Total Number of Valid Inferences with Text Type.

Dimensions of Personal Epistemology: Certainty, Simplicity, Source and Justification

Preliminary Analyses

This section presents analyses conducted to examine the effects of Text Type as the independent variable of the study on Explicit Personal Epistemology as reflected in each of the four dimensions of Certainty, Simplicity, Source and Justification. No corresponding analyses were conducted for Implicit Personal Epistemology because of the low reliability of individual scales. Preliminary analyses indicated that all four dimensions of Explicit Personal Epistemology were normally distributed (skewness and kurtosis<1). As it can be seen in Table 25 all four dimensions, except Certainty and Simplicity at the Pretest, were significantly correlated with each other at the Pretest and the Posttest.

Table 25

Correlations of the Four Dimensions at the Pretest and the Posttest

	Simp. (pre)	Sour. (pre)	Just. (pre)	Cert. (post)	Simp. (post)	Sour. (post)	Just. (post)
Cert. (pre)	.13	.29*	.40*	.44**	.23**	.28**	.17**
Simp. (pre)		.27**	.20**	.26**	.47**	.30**	.23**
Sour. (pre)			.42**	.25**	.34**	.32**	.21**
Just. (pre)				.33**	.34**	.22**	.30**
Cert. (post)					.43**	.33**	.43**
Simp. (post)						.44**	.46**
Sour. (post)							.36**

* $p < .05$. ** $p < .01$.

Paired samples t-test analyses were conducted to examine changes in scores from the Pretest to the Posttest for each dimension. It can be seen in Table 26 that although scores on all four dimensions increased, only the change in the Simplicity dimension was significant, $t(174) = -2.46$, $p = .015$.

Table 26

Mean Scores of the Four Dimensions at the Pretest and the Posttest

	Pretest	Posttest	t	Sig	Cohen's d
Certainty	0.55 (0.91)	0.65 (0.87)	-1.45	.149	0.11
Simplicity	1.31 (1.08)	1.53 (1.16)	-2.46	.015	0.20
Source	1.65 (1.23)	1.73 (1.36)	-0.70	.486	0.06
Justification	1.25 (1.18)	1.44 (1.13)	-1.76	.081	0.16

Note. N=175; Standard deviations are shown in parentheses.

To examine equivalence of the three text groups in each dimension four one-way analyses of variance (ANOVA) were performed, with scores of each dimension at the Pretest as a dependent measure and Text Type as the independent measure. None of these analyses reached significance indicating that the three text groups were equivalent in all four dimensions at the beginning of the study, Certainty: $F(2,172) = 0.10$, $p = .905$; Simplicity: $F(2,172) = 0.41$, $p = .664$; Source: $F(2,172) = 0.18$, $p = .833$; Justification: $F(2, 172) = 1.10$, $p=.334$. Moreover, differences among the three groups in each of the four dimensions at the end of the study were also examined with the use of one-way ANOVA. Again, none of the differences reached significance, Certainty: $F(2,172) = 1.87$, $p = .157$; Simplicity: $F(2,172) = 0.00$, $p = .999$; Source: $F(2,172) = 1.30$, $p = .275$ and Justification: $F(2,172) = 0.99$, $p = .374$.

Analyses were subsequently undertaken in order to examine change in each dimension over the course of the study. First, the correlations of each dimension with the other variables of the study were examined and subsequently multiple regression analyses were performed for each dimension in order to specify significant predictors of each dimension. These analyses are presented in the four subsections that follow.

Certainty

Correlations with other variables. As it can be seen in Table 27, Certainty at the Pretest correlated significantly with Prior Knowledge in Science (PKS), Teacher-Rated Text Comprehension Ability (TRAT), Total Number of Valid Inferences (TNVI) and Text Main Idea Recall (TMI). It did not correlate significantly with Personal Interest in Science (PIS), Text Comprehension-Recall Score, Situational Interest (SIT) and Mean Overall Recall Score (MORS). Certainty at the Posttest correlated with the same variables and also with Text Comprehension- Recall Score (TC-RS).

Table 27

Correlations between Certainty at the Pretest and the Posttest with the other variables of the study

	PIS	PKS	TC-RS	TRAT	SIT	MORS	TNVI	TMI
Certainty (Pre)	.02	.31**	.12	.42**	.03	.06	.22**	.25**
Certainty (Post)	.06	.26**	.17*	.44**	.07	.00	.21*	.37**

* $p < .05$. ** $p < .01$.

Predictors of Certainty at the Posttest. Multiple regression analysis was performed in order to specify significant predictors of Certainty at the Posttest. The following variables were all entered in one step: Certainty at the Pretest, Personal Interest in Science (PIS), Prior Knowledge in Science (PKS), Text Comprehension-Recall Score(TC-RS), Teacher-Rated Text Comprehension Ability (TRAT), Situational Interest (SIT), Mean Overall Recall Score (MORS), Total Number of Valid Inferences (TNVI) and Text Main Idea Recall (TMI). Outcomes indicated that the resulting model explained 28% (Adj. Model R^2=.28) of the variance observed in the dependent variable. Certainty at the pretest emerged as the most significant predictor ($\beta = 0.29$, $t = 3.78$, $p = .000$), followed by TRAT ($\beta = 0.24$, $t = 2.63$, $p = .009$) and also TMI ($\beta = 0.20$, $t = 2.44$, $p = .016$).

Advancement in Certainty. To decipher change in this dimension over the course of the study a repeated measures analysis of covariance (RM-ANCOVA) was performed, with Time as the within subjects factor with two levels (Certainty Pretest and Certainty Posttest). Text Type was entered as the between subjects factor, while Teacher-Rated Text Comprehension Ability (TRAT) and Text Main Idea Recall (TMI) (that emerged from the regression analysis as significant predictors of Certainty at the Posttest) were used as covariates. A Time x Text x TRAT multivariate interaction effect emerged, $F(2,165) = 5.42$, $p = .005$, $\eta^2 = .06$. Also, between subjects effects indicated a significant effect of Teacher-Rated Text Comprehension

Ability (TRAT), $F(1,165) = 16.78$, $p = .000$, $\eta^2 = .09$, an effect of Text Main Idea Recall (TMI) $F(1,165) = 7.68$, $p = .006$, $\eta^2 = .04$ and also a TRAT x TMI effect, $F(2,165) = 5.73$, $p = .018$., $\eta^2 = .03$.

To examine the TRAT x TMI between subjects effect, the variable Text Main Idea Recall was dichotomized at the median (*Mdn* = 5) to create two distinct groups, one with lower Text Main Idea Recall scores (TMI < 5) and one with higher Text Main Idea Recall scores (TMI >5). The means of Certainty at the Pretest and the Posttest are presented in Table 28 as a function of the interaction of Teacher-Rated Text Comprehension Ability (TRAT) with Text Main Idea Recall (TMI). The mean scores of Certainty at the Posttest were higher in the higher Text Main Idea Recall group compared to the corresponding means in the lower Text Main Idea Recall group, in all levels of Teacher-Rated Text Comprehension Ability, except for the students with high comprehension ability. Independent samples t-test were performed to examine the differences between the two groups of Text Main Idea Recall in all levels of Teacher-Rated Text Comprehension Ability. Results indicated that the differences were not significant ($p > .05$).

Table 28

Means on Certainty at the Posttest as a function of the interaction of Teacher-Rated Text Comprehension Ability with Text Main Idea Recall

	Text Main Idea Recall		
	Lower	Higher	Cohen's *d*
TRAT			
3	0.09 (0.67)	0.53 (0.71)	0.64
4	0.50 (0.81)	0.60 (0.93)	0.11
5	1.15 (0.96)	1.01(0.69)	0.17

Note. Standard deviations are shown in parentheses; There were five students with low comprehension ability (TRAT=2) in the lower TMI group and only one in the higher TMI group. Their data were not considered for the analysis presented in this table.

The interaction between Teacher-Rated Text Comprehension Ability and the Text Main Idea Recall was rather unexpected because both variables represented indices of Text Comprehension and as such they were not expected to interact with each other. Table 29 shows that not all students within each level of text comprehension could equally recall the main idea of the text. Most importantly, it shows that students who could more accurately recall the main idea of the text had lower scores on the Certainty at the Posttest compared to their peers who recalled the main idea less accurately. This finding was intriguing and needed thus to be more extensively examined. Consequently, the means of Certainty at the Posttest were also examined in respect to Text Type and Total Main Idea Recall. It can be seen in Table 29 that the means on Certainty at the Posttest were higher for the higher Text Main Idea Recall group compared to the lower Text Main Idea Recall group for all three text groups. The differences however, were not significant for the Baseline and the Refutation Text groups ($p > .05$), while the difference approached significance in the Analogy Text group (p=.056).

Table 29

Means on Certainty at the Posttest as a function of the interaction of Text Type with Text Main Idea Recall

	Text Main Idea Recall			
	Lower	Higher	t	Sig
Baseline	0.41(0.69)	0.57 (0.85)	-.76	.450
Refutation	0.63(0.90)	0.90 (0.78)	-1.24	.222
Analogy	0.49(1.13)	0.97 (0.74)	-1.95	.056

Note. Standard deviations are shown in parentheses.

In order to examine possible effects of Text type on the scores of Certainty at the Posttest also as a function of Teacher-Rated Text Comprehension Ability, the mean scores of Certainty at the Posttest are presented in Table 30 as a function of an interaction of Text Type with Teacher-Rated Text Comprehension Ability. The means of each text group for each level of Teacher-Rated Text Comprehension Ability were compared with one-way analyses of variance (ANOVA). Results indicated that the differences among the three groups were significant only for the high comprehension ability students. Post-hoc comparisons showed that the mean scores on Certainty at the Posttest were significantly higher in the Analogy Text group compared to the Baseline text group *(p* = .011). Differences between the Refutation group and the Baseline group, or between the Refutation group and the Analogy group were not significant ($p > .05$). The analyses undertaken to examine the intriguing interaction between Teacher-Rated Text Comprehension Ability and Text Main Idea Recall indicated that: a. there were students with high comprehension ability, who could accurately and sufficiently recall the main idea of the text, but had nevertheless lower scores on Certainty at the Posttest (compared to students who recalled the main idea of the text less accurately) and b. despite this inconsistency, the finding that students who had high comprehension ability and read the analogy text had higher scores at the Posttest of Explicit Personal Epistemology remained reliable.

Table 30

Means on Certainty at the Posttest as a function of an interaction of Text Type with Teacher-Rated Text Comprehension Ability

	Baseline	Refutation	Analogy	F	Sig
TRAT					
3	0.18(0.77)	0.01(0.54)	0.27(0.71)	0.30	.747
4	0.47(0.87)	0.66(0.83)	0.43(0.91)	0.46	.634
5	0.67(0.57)	1.13(0.80)	1.32(0.84)	4.59	.013

Note. Standard deviations are shown in parentheses; There were no any students with low Comprehension Ability (TRAT=2) in the Baseline group, while there were only 2 students in the Refutation group and 4 students in the Analogy group and thus their scores were not presented in the table. Differences between them were not significant, $p > .05$.

To examine the Time x Text x TRAT interaction the mean scores of Certainty at the Pretest and the Posttest were compared as a function of Text Type and Teacher-Rated Text Comprehension Ability (Table 31).

Table 31

Means of Certainty at the Pretest and the Posttest as a function of the interaction of Text Type with Teacher-Rated Text Comprehension Ability

	Baseline		Refutation		Analogy	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
TRAT						
2 [a]	-		0.00(0.24)	0.27(0.00)	-0.27(0.62)	-0.54(0.60)
3	-0.28(0.56)	0.18(0.77)	-0.29(0.75)	0.01(0.54)	0.05(0.73)	0.27(0.71)
4	0.58(0.76)	0.47(0.87)	0.64(1.14)	0.66(0.83)	0.71(0.81)	0.43(0.91)
5	0.98(0.93)	0.67(0.57)	0.74(0.70)	1.13(0.80)	0.90(0.80)	1.32(0.84)

Note. Standard deviations are shown in parentheses.

[a] There were not any students with low Comprehension Ability (TRAT =2) in the Baseline group, while there were only two in the Refutation group and four in the Analogy group.

In the baseline group students with average comprehension ability increased their scores on Certainty from the Pretest to the Posttest, while students with very good and high comprehension ability decreased their scores. In the refutation group students from all text comprehension ability levels increased their scores from the Pretest to the Posttest. In the analogy group students with low and very good comprehension ability decreased their scores from the Pretest to the Posttest, whilst students with average and high comprehension ability increased their scores. Paired samples t-tests indicated that the gains demonstrated by students with high comprehension ability in both the refutation and the analogy text groups were significant, $t(23) = -2.30$, $p = .031$ and $t(25) = -2.50$, $p=.020$ respectively. Any other changes in scores were nonsignificant ($p > .05$).

Simplicity

Correlations with other variables. It can be seen in Table 32 that as with the Certainty dimension, Simplicity was correlated significantly with all the other variables of the study, except with Personal Interest in Science (PIS), Situational Interest (SIT) and Mean Overall Recall Score (MORS). The highest correlations were observed between Simplicity at the Posttest with the variables Teacher-Rated Text Comprehension Ability (TRAT) and Text Main Idea Recall (TMI).

Table 32

Correlations between Simplicity at the Pretest and the Posttest with the other variables of the study

	PIS	PKS	TC-RS	TRAT	SIT	MORS	TNVI	TMI
Simplicity (Pre)	.05	.19*	.16*	.34**	.04	.05	.22**	.30**
Simplicity(Post)	.12	.25**	.32**	.52**	.11	.12	.29**	.45**

* $p < .05$. ** $p < .01$.

Predictors of Simplicity at the Posttest. A multiple regression analysis was subsequently performed to investigate the effect of other variables in the study on Simplicity at the Posttest. All the covariates presented in the preceding table along with Certainty at the Pretest were entered simultaneously. The model predicted 39% of the variance in Simplicity (Posttest), (Adj. Model $R^2 = .39$), while its significant predictors where the same as those that emerged for the Certainty dimension. Thus, Simplicity at the pretest ($\beta = 0.29$, $t = 4.26$, $p = .000$), TRAT ($\beta = 0.29$, $t = 3{,}60$, $p = .000$) and TMI ($\beta = 0.20$, $t = 2.63$, $p = .010$) were the variables that could reliably predict Simplicity at the Posttest.

Advancement in Simplicity. According to the results of this regression analysis, a Repeated Measures Analysis of Covariance (RM-ANCOVA) was designed in order to examine advancement within the Simplicity dimension. Again, Time with two levels (Simplicity at the Pretest and the Posttest) was used as the within subjects factor, Text was used as the between subjects factor, and Teacher-Rated Text Comprehension Ability (TRAT) and Text Main Idea Recall (TMI) were entered as covariates. The multivariate effects were not significant. There was however, a multivariate interaction Time x Text x TRAT effect that approached significance, $F(2,165) = 2.88$, $p = .059$, $\eta^2 = .03$. A between subjects Text main effect emerged, $F(2,165) = 3.46$, $p = .034$, $\eta^2 = .04$ and also a Text x TRAT interaction effect, $F(2,165) = 4.71$, $p = .010$, $\eta^2 = .05$.

The interaction of Text with Teacher-Rated Text Comprehension Ability was further examined. Table 33 presents the means of Simplicity at the Posttest as a function of Text and Teacher-Rated Text Comprehension Ability. One-way analyses of variance (ANOVA) examined the differences in the three text groups for each level of Teacher-Rated Text Comprehension Ability. Results indicated that differences between the three groups in either low, medium or very good comprehension ability were not significant ($p > .05$). However, differences among the three groups were significant for students with high comprehension ability (TRAT=5), $F(2,69) = 4.29$, $p = .017$. Post-hoc comparisons indicated that students with high comprehension ability who read the analogy text outperformed their counterparts in the baseline text group, $p = .020$. There were not any significant differences between students in the baseline and the refutation groups or between students in the refutation and the analogy groups ($p > 0.05$).

Table 33

Means on Simplicity at the Posttest as a function of the interaction of Text Type with Teacher-Rated Text Comprehension Ability

	Baseline	Refutation	Analogy
TRAT			
2 [a]	-	-0.21 (0.23)	-0.55 (0.30)
3	1.12 (1.09)	1.19 (0.46)	0.49 (0.83)
4	1.53 (1.12)	1.32 (0.94)	1.22 (1.06)
5	1.80 (0.94)	1.98 (1.08)	2.58 (0.90)

Note. Standard deviations are shown in parentheses.

[a] There were not any students with low Comprehension Ability in the Baseline group (TRAT=2), while there were only two in the Refutation group and four in the Analogy group.

Source

Correlations with other variables. Table 34 presents the correlations of Source at the Pretest and the Posttest with the other variables of the study. To some extent the pattern of correlations was again similar with the pattern of correlations that also emerged with Certainty and Simplicity. Source at the Pretest and Source at the Posttest were correlated significantly with the other variables, except with Personal Interest in Science (PIS) and Situational Interest (SIT). It did however correlate also with Mean Overall Recall Score (MORS) at the Posttest (this correlation did not appear significant for the dimensions of Certainty and Simplicity).

Table 34

Correlations between Source at the Pretest and the Posttest with the other variables of the study

	PIS	PKS	TC-RS	TRAT	SIT	MORS	TNVI	TMI
Source (Pre)	-.05	.23*	.22*	.35**	.04	.10	.25**	.27**
Source (Post)	.07	.29**	.20*	.36**	.09	.16*	.28**	.45**

* $p < .05$. ** $p < .01$.

Predictors of Source at the Posttest. A multiple regression analysis examined the impact of the variables presented in Table 34 on Source at the Posttest. All the variables that appear in Table 34 were entered in one step. The model explained 24% of the observed variance in Source at the Posttest, (Adj. Model $R^2 = .24$). Unlike the results of the multiple regression analyses conducted for Certainty and Simplicity, TRAT did not appear as a significant predictor. The only reliable predictors were Text Main Idea Recall (TMI), β = 0.29, $t = 3.41$, $p = .001$ and Simplicity at the Pretest, β = 0.16, $t = 2.06$, $p = .041$.

Advancement in Source. The repeated measures analysis of covariance (RM-ANCOVA) conducted for Source with Time as the within subjects factors with two levels (Source at the Pretest and Source at the Posttest), Text as the independent variable and Text Main Idea Recall (TMI) as the covariate indicated that there was a main effect of Time, $F(1,169) = 4.76$, $p = .031$, $\eta^2 = .03$ and a Time x TMI interaction effect, $F(1,169) = 6.19$, $p = .014$, $\eta^2 = .04$. In terms of the between subjects effects, there was a highly significant main effect of TMI, $F(1,169) = 42.31$, $p = .000$, $\eta^2 = .200$. To investigate the Time x TMI interaction, the dichotomized Text Main Idea Recall variable was used in order to calculate the mean scores on Source at the Pretest and the Posttest. Table 35 presents the mean scores on Source as a function of the interaction of Time with Text Main Idea Recall. As it can be seen the mean scores for the students in the lower TMI group decreased from the Pretest to the Posttest. On the contrary, the means for the students in the higher TMI group increased.

Table 35

Means on Source as a function of the interaction of Time with Text Main Idea Recall

	Pre	Post	Cohen's *d*
Lower TMI	1.38 (1.21)	1.36 (1.33)	0.02
Higher TMI	1.97 (1.19)	2.17 (1.27)	0.16
Cohen's *d*	0.49	0.62	

Note. Standard deviations are shown in parentheses.

To investigate changes in scores between the three text groups, means on Source at the Pretest and the Posttest were also examined as a function of an interaction of Text Main Idea Recall with Text Type. As it can be seen in Table 36 students who read the analogy text and achieved higher Text Main Idea Recall scores showed significant gains in the Source Dimension of Explicit Personal Epistemology. No other changes were significant ($p > .05$). This result supplements the observed changes in Source mean scores from the Pretest to the Posttest presented in Table 35, showing that students in the higher Text Main Idea Recall group in the Baseline and the Analogy text groups increased their scores from the Pretest to the Posttest. It also shows that only the gains manifested by students in the Analogy group were significant.

Table 36

Means on Source at the Pretest and the Posttest as a function of Text Type and Text Main Idea Recall

		Pretest		Posttest		t	Sig
	n	M	SD	M	SD		
Lower TMI							
Baseline	35	1.38	(1.21)	1.70	(1.39)	-1.26	.217
Refutation	29	1.34	(1.05)	0.96	(1.08)	1.44	.160
Analogy	32	1.42	(1.36)	1.34	(1.41)	0.25	.803
Higher TMI							
Baseline	22	1.91	(1.20)	2.13	(1.20)	-0.69	.500
Refutation	29	2.10	(1.43)	2.02	(1.36)	0.27	.789
Analogy	28	1.88	(0.89)	2.36	(1.26)	-2.25	.033

Justification

Correlations with other variables. Table 37 presents the correlations of Justification at the Pretest and the Posttest with the other variables in the study. Again, the correlations of Justification with other variables followed a more or less similar pattern with the other three dimensions (Certainty, Simplicity and Source). Justification at the Pretest correlated significantly with all the other variables besides Personal Interest in Science (PIS), Situational Interest (SIT) and Mean Overall Recall Score (MORS), while Justification at the Posttest correlated significantly with all the other variables with the exception of Personal Interest in Science (PIS), Situational Interest (SIT), Mean Overall Recall Score (MORS), and Total Number of Valid Inferences (TNVI). The highest correlations were again observed between Justification and Teacher-Rated Text Comprehension Ability (TRAT) and Text Main Idea Recall (TMI) both at the Pretest and the Posttest.

Table 37

Correlations between Justification at the Pretest and the Posttest with the other variables of the study

	PIS	PKS	TC-RS	TRAT	SIT	MORS	TNVI	TMI
Justification (Pretest)	.10	.31**	.27**	.41**	.04	.06	.33**	.36**
Justification (Posttest)	.04	.19*	.27**	.40**	.02	.12	.15	.35**

* $p < .05$. ** $p < .01$.

Predictors of Justification at the Posttest. A multiple regression analysis for Justification at the Posttest with all of the above variables and with the addition of Justification at the Pretest, all entered simultaneously, resulted in a model that explained 17% of the variance in Justification at the Posttest (Adj. Model R^2=0.17), TRAT, $\beta = 0.23$, $t = 2.49$, $p = .014$ and TMI, $\beta = 0.19$, $t = 2.08$, $p = .040$ appeared as significant predictors of Justification at the Posttest.

Advancement in Justification. The two variables Teacher-Rated Text Comprehension Ability (TRAT) and Text Main Idea Recall (TMI) were subsequently entered in a repeated measures analysis of covariance (RM-ANCOVA) as covariates, where Time with two levels (Justification at the Pretest and Justification at the Posttest) was used as the within subjects factor and Text Type as the between subjects factor. Results indicated a Time x Text x TRAT interaction effect, $F(2,165) = 4.30$, $p = .015$, $\eta^2 = .05$. Concerning the between subjects effects, there was a Text x TMI effect $F(2,165) = 3.13$, $p = .046$, $\eta^2 = .04$ and also a Text x TRAT interaction effect, $F(2,165) = 3.33$, $p = .038$, $\eta^2 = .04$.

The means of Justification at the Pretest and the Posttest were examined as a function of Text Type and Teacher-Rated Text Comprehension Ability. As it can be seen in Table 38 students' scores in the baseline group with average and very good comprehension ability increased from the Pretest to the Posttest, while the scores of students with high comprehension ability in the baseline group decreased. In the refutation text group, students with low, average and very good comprehension ability increased their scores from the Pretest to the Posttest, while the scores of students with high comprehension ability decreased. In the analogy text group students with low and average text comprehension ability decreased their scores after reading, while the scores of students with very good and high comprehension ability increased their scores from the Pretest to the Posttest. Paired samples t-tests indicated that only the increase in the mean scores of students who read the analogy text and with high comprehension ability was statistically significant, $t(25) = -2.43$, $p = .022$. All other changes in scores were not significant ($p > .05$).

Table 38

Means on Justification at the Pretest and the Posttest as a function of the interaction of Text Type with Teacher-Rated Text Comprehension Ability

	Baseline		Refutation		Analogy	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
TRAT						
2[a]	-		0.88(0.83)	1.03(0.55)	0.22(0.75)	-0.17(0.66)
3	-0.64(1.00)	1.03(1.02)	0.60(0.55)	1.09(0.94)	0.59(1.54)	0.28(1.02)
4	0.79(1.29)	1.32(1.30)	1.18(1.02)	1.50(1.05)	1.18(1.00)	1.32(0.98)
5	1.78(1.13)	1.47(1.04)	2.00(1.12)	1.89(1.11)	1.65(0.93)	2.21(0.81)

Note. Standard deviations are shown in parentheses.

[a] There were not any students with low Comprehension Ability (TRAT=2) in the Baseline group, while there were only two in the Refutation group and four in the Analogy group.

In order to examine the interaction of Text with Text Main Idea Recall, the dichotomized TMI variable was used to define two groups, one with lower Text Main Idea Recall scores and one with higher Text Main Idea Recall scores. The differences among the three groups in either the lower Text Main Idea Recall group or the higher Text Main Idea Recall group presented in Table 39 were not significant ($p > .05$). However, the differences between students with lower Text Main Idea Recall scores and students with higher Text Main Idea Recall scores in the Baseline Text group and the Refutation Text group, were significant, as indicated by independent samples t-tests, $t(55) = -3.39$, $p = .001$ and $t(56) = -2.20$, $p = .032$, respectively. Corresponding differences in the Analogy Text group were not significant ($p > .05$).

Table 39

Means on Justification at the Posttest as a function of the interaction of Text Type with Text Main Idea Recall

	Baseline	Refutation	Analogy
Lower TMI	0.91 (1.07)	1.30 (1.12)	1.14 (1.40)
Higher TMI	1.93 (0.91)	1.89 (0.93)	1.71 (0.86)
Cohen'*d*	1.03	0.57	0.49

Note. Standard deviations are shown in parentheses.

This chapter examined the impact of the two text-based interventions (refutation text and analogy text) on advancing Explicit and Implicit Personal Epistemology in Science taking into account the impact of Text Comprehension (Ability and Performance) that emerged as significant predictor of Personal Epistemology. Advancement was also examined within each of the four dimensions of Certainty, Simplicity, Source and Justification. This chapter also examined the variables that influenced the Comprehension of the instructional texts. Interpretation and implications of findings follow in Chapter 5.

CHAPTER 5

Discussion

The primary aim of this study was to examine the impact of short-term instructional interventions in the personal epistemology advancement of sixth grade students in science. In particular, this study was designed to compare two text-based interventions that stemmed from two different theoretical frameworks in personal epistemology: the *refutation text intervention* that stemmed from *the epistemological theories framework* (Hofer & Pintrich, 1997) and the *analogy text intervention* that emerged from the *epistemological resources framework* (Hammer & Elby, 2002). The impact of interest, prior knowledge and text comprehension on the effectiveness of the interventions was examined. The findings of the study provide support of the overall positive impact of the short-term text-based interventions on students' personal epistemology advancement. The results indicated that all three texts (the baseline, the refutation and the analogy) facilitated to a certain extent advancement of personal epistemology. Nevertheless, the analogy text had a substantial impact on personal epistemology advancement, but only for students with high comprehension ability.

The study aimed also to examine the reliability of Personal Epistemology in Science Questionnaire (PESQ), a newly developed domain-specific personal epistemology instrument, designed for sixth grade students. With the use of this domain-specific instrument the study examined the underlying structure of personal epistemology of sixth grade students in science, intending to investigate whether a four-dimensional structure could be supported in this younger age group. Results indicated that the reliability of PESQ was satisfactory, while the four-dimensional structure was not fully supported. Although the investigations related to the reliability of PESQ and the underlying structure of personal epistemology were introduced by the third research question of the study, the discussion of findings related to this question will be presented first, as their understanding is required for the interpretation of the results related to the other two research questions.

Measurement of Personal Epistemology in Science

Three issues were raised by the third research question: (a) the extent to which a domain specific instrument in science could reliably measure the personal epistemology of 11-12 year old students in science, (b) the form of items that seemed to be more appropriate for this younger age group (dichotomous agree/disagree items or scenarios), and (c). the manifestation of the hypothesized multidimensional structure in this younger age group. The

Personal Epistemology in Science Questionnaire (PESQ) was designed and developed on the basis of three objectives: (a) emphasize students' views about scientists' work avoiding items that referred to students' own practices in studying science, (b) stress domain specificity at the item level and directly relate items to the four dimensions via the ten subscales, and (c) keep language and expression clear and simple. Moreover, a previous version of this instrument was pilot-tested and results indicated that its reliability was satisfactory. It was therefore expected that the new version of PESQ, that reflected improvements in format and content as a result of the pilot, would reliably measure sixth grade students' personal epistemology in science. Moreover, it was expected that Part A (explicit personal epistemology) and Part B (implicit personal epistemology) of PESQ would be comparable in terms of reliability because both parts were developed on the basis of the three objectives outlined above. Rasch analysis of both parts of PESQ yielded satisfactory item and person reliability indices for Part A, but less so for Part B.

Reliability of PESQ

Explicit Personal Epistemology (Part A). It should be noted that a previous likert-scale (1-5) item format of PESQ administered for the purposes of the main pilot study yielded poor item and person reliability indices. Recoding of data into a dichotomous agree/disagree format resulted in improved reliabilities and yielded a good model fit. That finding indicated perhaps that when personal epistemology likert scale items are presented to students of 11-12 years old, may possibly cause confusion because a scale of 1-5 requires fine distinctions in one's epistemology that young students of this age may not be ready to make accurately and consistently. The pilot study provided evidence that dichotomous agree/disagree items may be more suitable in that regard. Consequently, the agree/disagree item format was used in the revised version of the Personal Epistemology in Science Questionnaire. This newer version of PESQ was used in the main study and analysis indicated that the reliability of Part A of the instrument was satisfactory. Results showed that the item reliability estimates for the pretest and the posttest were high, while person reliability estimates for the pretest and the posttest were good. Comparatively lower reliabilities at the person level may possibly indicate that although alignment between person performance and item difficulty was to some extent adequate, it was not nevertheless the expected. Person performance was relatively higher than the item difficulty. This means that the performance of students with more advanced personal epistemology was not adequately measured. This finding illustrates that perhaps more challenging items were needed in order to more reliably measure personal epistemology of all participants. The current version of PESQ was the result of successive revision cycles of an original format that primarily emerged from the GEBEP (Greek Epistemological Beliefs in Physics) appropriate for middle school students, which was reported to have good reliability established with Cronbach's alpha reliability analysis (Stathopoulou &Vosniadou, 2007). In this study the reliability of PESQ was established with the use of Rasch modeling. However, item reliability estimates can be interpreted in the same way as Cronbach's alpha is interpreted, i.e. as an internal consistency measure (Bond & Fox, 2001). In that sense, reliability of PESQ can be considered very good and improved in comparison with the reliability of the GEBEP. Improved reliability can be interpreted as the result of efforts to develop a domain specific instrument at the item level, focused on students' views about scientists' work, avoiding at the same time items that referred to learning beliefs.

Reported reliability indices in previous studies that examined elementary school students' personal epistemology in science corresponded to individual subscales and not to the instruments as a whole. Conley et al. (2004) reported reliabilities of individual subscales ranging from average to very good and Elder (2002) reported reliabilities of individual subscales ranging from average to good. Direct comparisons with the results of these studies however cannot be made as the reported reliabilities concern individual subscales.

Implicit Personal Epistemology (Part B). In this part of PESQ personal epistemology was measured indirectly via the use of short scenarios that presented the discussion of two children who had different opinion on issues related to epistemology in science. The response format of scenarios represented essentially a five point likert scale. Results yielded poor item reliability estimates both at the pretest and the posttest, while person reliability estimates were acceptable at both testing times. Reliability improved after recoding of data into a dichotomous agree/disagree format, yielding satisfactory reliabilities at the item level both at the pretest and the posttest and acceptable reliabilities at the person level both at the pretest and the posttest. Similar to reliability issues at the person level observed in Part A of PESQ, person reliability estimates in Part B of PESQ were also comparatively lower than the item reliability estimates. Again, this result indicates a relative mismatch between person performance and item difficulty, showing that person performance was higher than the item difficulty (Bond and Fox, 2001). The mismatch between item difficulty and person performance shows that the personal epistemology of high performers was not adequately assessed at the implicit level either. This ceiling effect observed in both parts of the Personal Epistemology in Science Questionnaire, may have implicated findings related to the first and the second research questions, by precluding manifestation of larger gains in personal epistemology, particularly for students with more advanced personal epistemologies. Lower reliability at the implicit measurement of personal epistemology, compared to the reliability reported for the explicit measurement of personal epistemology was also reported by Gill et al. (2004). Stathopoulou and Vosniadou (2007) who also employed the use of scenario-based assessment of personal epistemology did not report results of reliability analysis for this specific part of their epistemology instrument because they did not consider it separate from the part that examined personal epistemology with likert scale items.

Comparison of item format

Explicit Personal Epistemology was considered a distal measure of personal epistemology, while implicit personal epistemology was considered a proximal measure (Gill et al., 2004). Implicit measurement of personal epistemology entails indirect examination of students' views that avoids open confrontation of students with epistemological issues. Instead, students are asked to read the discussion of two children who disagree on epistemological issues and subsequently indicate the child they mostly agree with (and thus implicitly take an epistemological stance). It was assumed whatsoever that both explicit and implicit assessment of personal epistemology would be comparable in terms of reliability because their design and development was based on the same four dimensions reflected in the ten subscales. More importantly, the development of both measures was conducted on the basis of the same three objectives (emphasis on students' views about scientists' endeavors, domain specificity, simplicity in language and expression). However, this expectation was not fully confirmed as the assessment of implicit personal epistemology resulted in comparatively lower reliability estimates, particularly at the person level. If reliability of an instrument is an index of how appropriate it may be considered for a particular population, then the explicit assessment of personal epistemology may seem more appropriate for students of upper elementary school (11-12 years old), especially in the dichotomous agree/disagree item format.

It should not be ignored however, that significant positive correlations between these two facets of epistemology indicated possible ground between them. Taking into account both of them may provide more complete and useful information about students' epistemologies, especially younger students' epistemologies that are not well articulated. Perhaps the low reliabilities observed in this study in the measurement of implicit personal epistemology can be attributed to the scenarios-based examination. Students needed to comprehend the short texts that represented the short discussion of the two disagreeing children. Other instruments that may avoid this text-based examination of implicit personal epistemology may be more appropriate.

The four-dimensional structure

This research aimed to examine the extent to which the four dimensions of Certainty, Simplicity, Source and Justification introduced by Hofer and Pintrich (1997) would be manifested in sixth grade students. However, because the study involved primarily the comparison of two interventions that emerged from two different theoretical frameworks that support antithetical assumptions about the structure of personal epistemology, no explicit predictions were stated regarding the structure of personal epistemology.

A basic premise in Rasch modeling is that if a model is confirmed using the Rasch methodology then evidence is provided that the data support a unidimensional structure (Bond & Fox, 2001). However, an underlying unidimensional structure may encompass a number of interrelated subscales. The analysis of data using the Rasch modeling yielded satisfactory fit indices, both for explicit personal epistemology (Part A) and implicit personal epistemology (Part B) of the Personal Epistemology in Science Questionnaire (PESQ). This finding indicates that the structure of personal epistemology of sixth grade students may be considered unidimensional. It should be noted however, that if a structure is characterized as such, does not preclude the existence of interrelated subordinate structures. In turn, the interrelatedness of the subordinate structures results in one encompassing dimension, which is considered to reflect the measured variable. In this research, the four dimensions were positively and significantly correlated. The reliabilities of the four dimensions ranged from average to low at the person level, while they were considered satisfactory at the item level. This indicates that item separability was better than person separability and that one could place more confidence in the replicability of item placement among other samples, compared to replicability of person placement with a comparable measure (Bond & Fox, 2001). Consequently, if PESQ was administered to another sample with the same characteristics as the sample of this study, one would expect to replicate the finding concerning the presence of the four dimensions. The examination of the four dimensions in implicit personal epistemology indicated that while at the item level reliability was adequate, reliability was equal to zero for all four dimensions. However, for a model to be supported both item and case reliabilities should be satisfactory. The small number of items in each dimension may have resulted in the lack of reliability in the individual dimensions of implicit personal epistemology, which was assessed with scenarios (longer and harder to read compared to statements in Part A). Consequently, the numbers of scenarios that corresponded to each dimension could have not been bigger than four. Prior research with students of upper elementary school indicated that the reliability of multidimensional structures ranged from average (Elder, 2002) to satisfactory (Conley et al., 2004), even though the dimensions that emerged in these studies are not directly comparable to the four dimensions of Certainty, Simplicity, Source and Justification that were examined in the current study.

It was expected that the confirmation of a four-dimensional structure would provide support for the epistemological theories framework, while the lack of clearly emerging factors would strengthen the epistemological resources framework. The epistemological theories framework (Hofer &Pintrich, 1997) assumes that personal epistemology is theory-like (i.e. coherent and consistent) and expressed in four subscales of certainty, simplicity, source and justification (Hofer, 2004). It should be noted however, that it is the interrelatedness of the individual subscales that may support theory-like attributes of the measured variable. In this study, the four-dimensional structure was not fully supported as item and person reliability estimates were not equally high. However, results indicated that the four dimensions, despite the low reliabilities at the person level, were interrelated. Results also supported the unidimensionality of personal epistemology. Taken together, these results may characterize personal epistemology as an overall encompassing structure (unidimensional), possibly reflected in four interrelated dimensions. As a result, in regard to whether this research supports a theory-like view of personal epistemology, or a fragmented structure of personal epistemology, findings preclude strong statements, but provide partial support for the epistemological theories framework.

Unidimensionality without any evidence supporting the presence of individual subscales would point to parallels with developmental models of personal epistemology that assume a stage-like development of one hierarchically integrated structure (King & Kitchener, 1994; Belenky et al., 1998; Kuhn, 1999; Baxter Magolda, 2004). However, this study provides partial support for the expression of this encompassing structure into a set of interrelated dimensions. The basic premise in multidimensional models however is the support of a set of 'more or less' independent dimensions, each expressed on a continuum of more sophisticated (advanced) to less sophisticated (advanced) (Schommer-Aikins, 2002). Independence of dimensions however does not afford the characterization of the structure of personal epistemology as theory-like. Although Hofer and Pintruch (1997) support a theory-like view of personal epistemology, they have not consistently made the distinction of the degree to which dimensions are interrelated or not (Hofer, 2004) and as a result they have not specifically examined the interrelations between individual dimensions. Research conducted under the multidimensional models however, provide indirect evidence of the orthogonality of individual dimensions as they present different patterns of correlations of the individual dimensions with the variables of interest of each study (e.g. Conley et al., 2004; Braten & Stromso, 2004; Dahl, Bals, & Turi, 2005). Concerns have been expressed about the hypothesized orthogonality of multidimensional structures from the analysis of data collected with the use of well known instruments, e.g. the Epistemological Beliefs Survey (Wood & Kardash, 2002) from comparatively larger samples (DeBacker et al., 2008). In the present study the interrelatedness of the four dimensions of certainty, simplicity, source and justification has been supported via the application of Rasch modeling that provides more comprehensive accounts of the attributes of the instrument beyond the examination of the internal consistency of the measure. Indirect evidence about the interrelatedness of the four dimensions is also provided by the pattern of effects of the independent variable of the study on the four dimensions. Text type, to a large extent, had similar effects across the four dimensions.

In terms of the particular dimensions that emerged in studies conducted under the multidimensional paradigms, findings do not converge neither into the content nor to the number of the dimensions. This may be attributed to lack of: (a) domain specificity, (b) distinction between beliefs about knowledge and knowing from beliefs about learning, and (c) distinction between students' views about the work of scientists and students' views about their own efforts in science. The inconsistency of findings related to the number and the content of the dimensions may also be attributed to the factor analytic techniques that different researchers employed to investigate the emergence of dimensions. Exploratory Factor Analysis (EFA) has been most prominently used (e.g. Schommer, 1990; Schommer-Aikins, 2002) while Confirmatory Factor Analysis (CFA) (e.g. Jehng, Johnson, & Anderson, 1993) might be a more appropriate technique because it is guided by theory and provides a more stringent test of the hypothesized multidimensional structure. In this study, the application of Rasch modeling put to the test the hypothesized four-dimensional structure proposed by Hofer and Pintrich (1997) and Hofer (2004) and facilitated a rigorous examination of the underlying coherence of the four dimensions by confirming their interrelatedness.

Personal Epistemology Advancement

Explicit Personal Epistemology

The first research question was primarily concerned with the comparison of two text-based interventions (the refutation text and the analogy text) in terms of their effectiveness in facilitating sixth grade students' personal epistemology advancement in science. Moreover, it also concerned the examination of the impact of interest, prior knowledge and text comprehension in the effectiveness of the two interventions. The comparative nature of the study precluded the statement of directional hypotheses, regarding the superiority of one intervention over the other. It was expected however, that (a) both the refutation text and the analogy text would be more effective compared to the baseline (control) text, and (b) that effectiveness of any one of the two experimental texts would depend upon the underlying structure of personal epistemology.

Contrary to expectations, the results indicated that all three texts could induce change to a certain extent. Nevertheless, change, as indicated by a small effect size was rather modest. The small magnitude of change replicates previous findings of studies that focused on promoting personal epistemology of pre-service teachers (Gill et al., 2004) and also of upper elementary school students in science (Conley et al., 2004). The study by Conley et al. (2004) concerned the examination of change of fifth grade students' epistemology over the course of a nine-week hands-on science program that emphasized science process skills. This study provided evidence of change in two of the four dimensions of epistemology that were examined in the study. One study that reported substantial gains in personal epistemology as a function of instruction was reported by Smith et al. (2000) who focused on advancing the epistemology of elementary school students in science, by applying an inquiry-based curriculum that encouraged the investigations of phenomena, the statement of students' own hypothesis and the design of students' own experiments for the testing of their hypotheses. It should be noted however, that the Smith et al. (2002) study concerned the persistent efforts of one teacher who consistently trained her students using an inquiry-oriented curriculum for six years. The present study examined the effectiveness of instructional interventions that lasted 80 minutes only. Consequently, the small change observed in students' personal epistemology may to a certain extent be attributed to the short duration of the study.

Despite the overall moderate change in the personal epistemology of the participants of this study, substantial gains (as indicated by a large effect size) were consistently manifested by students who read the analogy text, but only for those who had high text comprehension ability. The basic premise in the design of the analogy text was to create a context that would activate productive epistemological resources (Hammer & Elby, 2002; 2003). The text featured analogies between everyday examples (e.g. how toys have changed over the years) and epistemological issues (e.g. how knowledge in science has changed over the years). Analogies were considered to play a role of 'bridging' or anchoring of students' common sense knowledge with more formal epistemological themes (Clement, Brown, & Zietsman, 1989; Hammer & Elby, 2002; 2003). The findings of this research indicate that, indeed such "bridging" may facilitate epistemological advancement, but only when students have high comprehension ability. There are two possible explanations for this finding. A student needed to have high comprehension ability in order to comprehend parallels between everyday examples and epistemological issues and be able to generate such inferences that would support understanding of the epistemological themes. Also, there was one possible danger with this text: examples from everyday life, despite their overall potential in activating relevant epistemological knowledge, could indeed distract students from the main idea of the text. The results indicated that there was a decrease in the personal epistemology scores of students with low, average and very good comprehension ability after reading. Although the decrease was not significant, it does indicate that excellent reading ability was required for one to focus on the similarities between everyday life and epistemology on the one hand, generate the appropriate inferences that would provide understanding of the similarities on the other, and moreover be able to avoid dwelling on insignificant aspects of the everyday examples per se, irrelevant to the main idea of the text. Further support for this explanation is provided by the finding that students with high prior knowledge and who read the analogy text generated more inferences compared to students who read the analogy text with low prior knowledge and also compared to their counterparts in the other two text groups. This indicates that indeed the analogy text was a cognitively demanding text that required both high comprehension ability and high prior knowledge. It represented a text that could by nature instigate the inference generation process, but high prior knowledge was needed in order to facilitate inference generation.

The second explanation of the finding that the analogy text benefited students with high comprehension ability is methodological. The intervention involved individual reading of the texts. There was no discussion of the texts after reading and students were not encouraged to ask clarification questions related to the substance of the texts. Students were asked to independently comprehend apparently challenging texts and therefore only those with high comprehension ability could manage accordingly. It should be noted however, that the design of the study did not involve discussion of text content to avoid the impact of possible extraneous factors that could confound the impact of the independent variable of the study.

The design and the development of the analogy text emerged from the epistemological resources framework (Hammer & Elby, 2002), building upon the idea of utilizing students' available everyday conceptions for the facilitation of more formal ones. Studies conducted under this framework however, were not experimental and their unit of analysis was not the individual student. They focused rather on classrooms as a whole (e.g. Louca et al., 2004; Hammer & Elby, 2003) or on the interactions of individual groups (e.g. Rosenberg et al., 2006). The reasoning behind their methods is that the resources are activated in situ depending largely on the particular context. These researchers could argue that the use of analogy text in the present study represented a 'fabricated' context that was imposed on students instead of allowing students shape the context with their available conceptions. Nevertheless, this study indicated that the use of analogies even in this 'fabricated' context may have a positive effect on students' personal epistemology, enabling possibilities of the effectiveness of this approach in other more realistic settings.

In addition to the effect of analogy text in facilitating personal epistemology of students with high comprehension ability, an analogous effect was also observed for the refutation text. Results indicated that the refutation text was particularly effective for those students who could accurately recall the main idea of the text. This outcome indicates that the refutation text was also a cognitively demanding text and that students needed perhaps to implement comprehension strategies in order to learn from it and facilitate their epistemology.

The refutation text in this study presented a less availing epistemological stance, refuted it and then provided science-based explanations that supported the availing epistemological stance that was directly relevant to the main theme of the text. For instance, the text that discussed the uncertainty of knowledge in science, provided an explanation derived from research about the shape of the earth in the old times, focusing on how the then new understanding of the spherical shape of the earth enabled a better explanation of the day-night cycle, stressing that knowledge in science changes when new theories provide better explanations of phenomena. Akin to the demanding cognitive processing required for the comprehension of analogies, students reading the refutation text need to navigate through the science-based explanations, comprehend them and eventually connect them to the main epistemological issue discussed in the text. Thus, students in the refutation text group needed to locate the main idea of the text in order to learn from it and subsequently advance their epistemology.

A similar, but less substantial effect of the interaction of the recall of the main idea with the type of the text was also observed for students in the analogy text and to a lesser extent to students in the baseline text. Despite that the interaction effect was more prevalent for students in the refutation group, a benefit was evident for all students of the three groups who could accurately recall the main idea of the text. Thus, the assumption about the level of difficulty of the analogy and the refutation text may also hold true for the baseline text, which was used as a control text. Although this text presented the same information about each epistemological issue discussed in each text, it lacked the examples and the explanations that were present in the analogy and the refutation text. In essence, a student reading the baseline expository text was required to generate inferences in order to establish the connections between the new information provided in the text and their own epistemological knowledge.

The use of the refutation text in this study originated from its use in conceptual change research. Its use in conceptual change research rests upon creating opportunities for cognitive conflict, a necessary prerequisite for knowledge restructuring (Hynd, 2001; Guzzetti et al., 1993). The refutation text has been used with relative success in studies with elementary school students (e.g. Diakidoy et al., 2003; Mason et al., 2008) and evidence was provided that the students who read the refutation text as opposed to those students who read standard expository texts engaged in revision of their knowledge to a greater extent. Refutation text has been used with relative success with older participants as well (Quian & Alvermann, 1995; Kendeou & van den Broek, 2005; Diakidoy et al., 2011) underlining its superiority to the standard expository text in terms of facilitating knowledge revision and restructuring.

Beyond its use for the advancement of learning, the refutation text was also employed for the purposes of epistemological advancement of pre-service teachers (e.g. Gill et al., 2004) providing support of change (however modest) in teachers' epistemic conceptions about instruction. A notable distinction between the text used in the Gill et al. (2004) study and the text used in the present study is that the text they employed addressed teachers' epistemic beliefs about instruction and not their personal epistemologies per se. Moreover, that study used also the technique of augmented activation along with the use of the refutation effect, precluding strong inferences about what caused change and if change was the result of a combined effect of refutation text with augmented activation. Kienhues et al. (2009) also reported the use of text for advancing the epistemology of college students. The text they used however, was not refutational, but had 'epistemological considerations'. This means that the text did not directly address epistemological issues per se, but it addressed topics that exemplified the uncertainty of knowledge. Despite the mixed results provided by the Kienhues et al. (2009) study, evidence indicated that the text facilitated the epistemological advancement of students who had less availing beliefs at the beginning of the study, while it did not have an effect on students with more advanced beliefs.

In this study the results do not strongly support the superiority of the refutation text over the baseline (expository) text and its effectiveness was evident only with high comprehension ability students. On the basis of these results, it can be reasoned that this finding might be due to an inherent difficulty of the particular refutation text as a function of its topic. The finding that only high comprehenders could benefit from the text indicates perhaps that asking elementary school students to read about epistemology is a challenging task.

Studies that use refutation text for the purposes of advancing learning of science conceptions take into consideration level and quality of prior knowledge (accurate vs. inaccurate) as both implicate the process of learning from refutation text (e.g. Kendeou & van den Broek, 2005; Diakidoy et al., 2011). In this study, the level but not the quality of prior knowledge (i.e. personal epistemology before the beginning of the study) was considered and this does not enable conclusions in that regard. The inclusion of text comprehension ability variables in the design of the study however, indicated their importance in implicating the effectiveness of the refutation text.

Implicit Personal Epistemology

A different pattern of change was observed in implicit personal epistemology. Implicit personal epistemology represented a proximal measure of personal epistemology (Gill et al., 2004) as it was assessed with scenarios that elicited students' views less directly and less formally, targeting their unarticulated epistemic stances. Neither type of text nor its interactions with variables that influenced explicit personal epistemology (e.g. text comprehension ability based on teachers' ratings, or recall of main idea) had any systematic impact on how students' implicit personal epistemology scores changed from the pretest to the posttest. Rather, there was a main effect of the number of inferences generated which showed that students who generated more inferences from reading the text had significantly higher scores on the posttest of implicit personal epistemology compared to students who generated fewer inferences from reading the text. When this effect was further examined within each text group, results indicated that the difference in the implicit personal epistemology at the posttest between students who generated more inferences and those who generated fewer inferences was particularly evident for students who read the baseline text and to a lesser extent for students who read the analogy text. This implies that the baseline text required substantial inference generation in order to benefit students' implicit personal epistemology.

One would expect that because implicit personal epistemology represented a proximal measure of personal epistemology, improvement in scores as a function of learning from the text would be evident more readily. Inference generation on the other hand, establishes coherence within text and facilitates integration of text content with readers' prior knowledge, leading thus to learning from text (Diakidoy et al., 2011). Consequently, number of inferences generated could be considered the comprehension measure in this study that most directly reflected learning from text (compared to general comprehension ability that influenced explicit personal epistemology). It could be therefore inferred that the proximal measure of personal epistemology in this study (implicit personal epistemology), reflected systematic effects of the proximal measure of learning from text (number of generated inferences).

The impact of inference generation was more prevalent than the impact of the type of text, the independent variable of the study, reinforcing the assumption that all three texts were cognitively demanding. The finding that students who generated more inferences outperformed those who generated fewer inferences particularly in the Baseline group and less so for students in the Analogy group supports an assumption that the three texts imposed perhaps a heavy cognitive load on students' part, each text for different reasons however. On the one hand, the baseline text, representing an expository text, simply stated epistemological 'facts' (e.g. that knowledge in science changes when new explanations of phenomena seem more viable). The reader of the baseline text needed therefore to engage in serious cognitive processing and inference generation in order to benefit from it. As it has already been mentioned, the analogy text on the other hand, demanded the establishment of connections between everyday examples and epistemological issues. Consequently, it also required inference generation. The fact that this finding did not emerge for the refutation text, may indicate that indeed the refutation text as a function of its structure that draws attention to the inconsistencies between misconceptions and more acceptable ideas, reduces cognitive load by 'taking over' the reader's task of locating such inconsistencies (Best, Rowe, Ozuru, & McNamara, 2005).

Advancement within dimensions of personal epistemology

Certainty. Findings concerning the dimension of certainty reinforce findings observed from the analyses of total scores of explicit personal epistemology. Students who read the analogy or the refutation texts and who had high comprehension ability manifested significantly higher gains compared to students who had high comprehension ability and read the baseline text and also compared to the gains demonstrated by students with very good, average and low comprehension ability. Again, this finding reinforces previous finding that both the analogy and the refutation text could benefit students, but only those who had the comprehension ability to meaningfully learn from the texts. Students who read the baseline text overall decreased their scores after reading and although the difference in scores was not significant it does provide an index that the baseline text may had possibly caused confusion to students who read it (including students with high comprehension ability) regarding the issue of uncertainty in science.

Simplicity. In this dimension of explicit personal epistemology students who read the analogy text and had high comprehension ability had significantly higher scores on the posttest compared to students who read the baseline text and had high comprehension ability. Again, this finding reinforces the superiority of the analogy text compared to the baseline text, but only for students with high comprehension ability.

Source. Students who had higher main idea recall scores increased their scores after reading, while those students who had low main idea recall scores decreased their scores after reading. Importantly, students who achieved high main idea recall scores in all three text groups increased their scores, but only students who read the analogy text increased their scores significantly after reading.

Justification. Students who read the analogy text and had high comprehension ability significantly increased their scores from the pretest to the posttest. This finding replicates results related to the analyses conducted with the overall scores of explicit personal epistemology. Moreover, students who read the baseline text and achieved high main idea recall scores outperformed students who read the baseline text and achieved low main idea recall scores on the dimension of justification at the posttest. This finding was also significant for students who read the refutation text, but to a lesser extent. This result shows that both the baseline and the refutation texts but particularly the baseline text required perhaps the application of comprehension strategies that would enable their readers to elicit the main idea of the text, in order to benefit from them.

In summary, the findings related to the dimensions of explicit personal epistemology reinforce findings related to the analyses conducted with the overall scores of explicit personal epistemology and stress two issues: (a) the analogy text was particularly effective for high comprehension ability students, and (b) all three texts benefited students' personal epistemology to the extent that they had the comprehension ability or had perhaps applied the appropriate comprehension strategies in order to find the main idea of the texts and learn from them.

These results afford certain interpretations from a developmental standpoint despite the fact that the study was conducted within a multidimensional paradigm on personal epistemology that did not examine general stage-like epistemological change and focused rather only in the domain of science. Per King and Kitchener (1994) individuals have both an optimal and a functional level. Similar to Vygotsky's (1978) of zone of proximal development, the difference between the two levels represents one's developmental range. Given that the optimal level is defined as what students may achieve with the support of adult-guided instruction, it can be then argued that the text-based interventions of this study enabled students operate at an optimal level. A basic prerequisite of this functioning however, was good comprehension ability.

Impact of Interest, Prior Knowledge and Text Comprehension

On the basis of the Model of Domain Learning (Alexander et al., 1995) it was hypothesized that more interested and more knowledgeable students in the domain of science would comprehend the experimental texts more effectively and that the interactional effect of interest, prior knowledge and comprehension would in turn influence personal epistemology advancement. This expectation was not fully confirmed by the results of the study.

Interest

Personal interest did not have any impact on the effectiveness of the interventions. This variable was assessed with a measure that considered students' interest in science compared to other school subjects like mathematics, history, language arts etc. It seems possible that such a general index of students' interest in science was not directly or indirectly related to epistemological issues in science that were primarily discussed in the experimental texts. Situational interest on the other hand, despite its potential to possibly impact the process of advancement due to its proximity with the process of reading the experimental texts (e.g. Ainley, Hidi, & Berndorff, 2002) did not surface as an important predictor of personal epistemology at the posttest. It can be reasoned that despite situational interest was considered to provide an index of students' engagement with texts, it eventually provided an index of students' liking of the texts. It seems that liking or not liking the text does not provide any useful information about the level of cognitive engagement when reading the text. A student could find a text boring but still comprehend and learn from it and a student could find a text interesting and yet not learn anything from it.

Prior Knowledge

There is mixed evidence concerning the role of prior knowledge in the process of advancement. Prior knowledge predicted explicit personal epistemology at the pretest, but it did not predict personal epistemology at the posttest and did not directly have any interactional effect on the process of advancement. This variable however, represented a measure of students' domain knowledge and thus it was not directly related to the text topic. It was reasoned however, that personal epistemology as it was measured at the beginning of the study would provide a measure of students' prior topic knowledge. While it was expected that both types of prior knowledge would impact the process of advancement, it seems that personal epistemology at the pretest, which essentially represented prior topic knowledge, was a more significant predictor of the process of advancement. Moreover, prior domain knowledge interacted with the type of text and influenced the number of valid inferences generated when reading the texts. This can be interpreted as an indirect impact of prior domain knowledge in the process of advancement.

Text Comprehension

It was expected that text comprehension would lie in the center of all important interactions that would eventually lead to personal epistemology advancement. Results confirmed this pivotal role of text comprehension. Results indicated that students with high comprehension ability and those who could accurately recall the main idea of the texts benefited the most from them facilitating as a result their personal epistemologies. It should be noted however, that two indices of text comprehension were considered in the study: (a) comprehension ability (as rated by the teachers and as an overall recall score of an expository text), and (b) comprehension performance (represented by three indices: overall recall score, number of valid inferences, and recall of main idea). Comprehension ability as rated by the teachers and recall of main idea seemed to exert systematic impact on the effectiveness of the interventions via their interactions with the type of the text. Another notable finding is that while comprehension ability as rated by the teachers and recall of main idea influenced personal epistemology at the explicit level on the one hand and number of valid inferences influenced personal epistemology at the implicit level on the other, both the overall recall score indicating comprehension ability and overall recall score indicating comprehension performance were the only variables that did not have any systematic impact on the process of advancement. This finding supports previous findings that memory for text does not predict learning from text (Kendou & van de Broek, 2007; Diakidoy et al., 2011).

Predictors of Text Comprehension Performance

The second research question aimed to investigate the impact of personal interest and prior knowledge on text comprehension (performance). Results indicated that prior knowledge interacted with type of text and influenced number of inferences generated from reading the texts. In particular, it was found that students with high prior knowledge in science and who read the analogy text generated more inferences after reading the texts. This finding indicates that the analogy text facilitated the inference generation process by virtue of its analogy-rich content, but that in order to engage in the inference generation process one needed also to have high prior knowledge. This result strengthens the possibility that the analogy text was indeed a cognitively demanding text. Importantly, the interaction of prior knowledge with text type also indicated that students with low prior knowledge and who read the refutation text generated more inferences compared to low prior knowledge students in the other two text groups. This result reinforces previous findings that the refutation text seems more effective in terms of inference generation and learning from text particularly with students who have low or inaccurate prior knowledge (Diakidoy et al., 2011).

Implications

Theoretical Implications

The overall aim of the first research question was to compare the two text-based interventions and indirectly provide evidence of the underlying structure of personal epistemology. In particular, it was expected that if there was evidence that the refutation text was more effective in enhancing students' personal epistemology advancement, indirect support would be provided towards the epistemological theories framework (Hofer & Pintrich, 1997). On the other hand, it was also assumed that if the analogy text would provide more facilitative effects in students' personal epistemology, then indirect support would be provided in favor of the epistemological resources framework (Hammer & Elby, 2002).

Results related to the first research question do not support the superiority of one intervention over the other. Mixed results about the effectiveness of the two interventions were provided. In particular, both the refutation text and the analogy text interventions were particularly effective with high comprehension ability students. Despite the fact that this result was particularly robust with the analogy text, not any strong statements are afforded regarding implications about the structure of personal epistemology because the effectiveness of any one of the two interventions referred only to a subgroup of the participating students (high comprehenders).

However, the issue of structure of personal epistemology was also directly examined by the third research question. Evidence derived from the examination of this question provided partial support of a theory-like organizational structure of sixth grade students' explicit personal epistemology in the domain of science. Results confirmed a unidimensional structure that is possibly reflected in four interrelated dimensions: certainty, simplicity, source and justification.

The overall modest change in students' personal epistemology over the course of the study may reinforce assumptions that personal epistemology represents a central structure in one's belief system with many functional connections to other beliefs (Pajares, 1992). As such, it may indeed be considered a structure resistant to change. It is this particular characteristic of personal epistemology that encouraged researchers to parallel the process of epistemological advancement with conceptual change and use methods applied in conceptual change research (e.g. refutation text) to facilitate epistemological advancement (e.g. Gill et al., 2004). Students' alternative conceptions in science are considered theory-like and show resistance to change (Vosniadou, 1994). This study has provided partial support that personal epistemology may also be considered theory-like and that it is a structure relatively resistant to change.

Practical Implications

The results of this study provide support in favor of the argument of researchers in the area (Schommer, 1990; Pajares, 1992; Elder, 2002; Schraw & Sinatra, 2004, Muis, 2008) on the importance of informing children in grade school (4-12 years old) about the integration and complexity of knowledge. Evidence is provided that instruction may have an impact on facilitating the personal epistemology of sixth grade students in science. Despite the fact that evidence of change was rather modest it provided support of the potential of instruction. It was reasoned that the magnitude of change could be attributed to the short duration of the study. Consequently, this may imply that more extensive instructional approaches may generate more robust changes in students' epistemologies. It should be noted however, that a goal of the present study was to examine feasible and at the same time less time consuming instructional interventions that schools and teachers would be eager to apply. This study shows that such short-term instructional interventions may indeed have an effect on students' personal epistemology.

In this study, pronounced effects were evident with high comprehension ability students. If what high comprehension readers can accomplish on their own represents an index of what can be accomplished in general, then at least equal gains may be achieved by students of lower comprehension ability when supported by classroom instruction. If, for instance, reading about how knowledge in science changes may have an effect, then other classroom activities related to text (e.g. whole class discussion, peer discussion on the content of epistemological texts) or unrelated to text (e.g. watching video excerpts from the news that talk about new findings in science that contradict previous ones) may enhance epistemic understandings. Moreover, because the analogy text seemed to induce change to a greater extent, despite that this was observed only with high comprehension ability students, it may point to a useful direction in teaching about epistemological issues. However, no analysis provided any direct evidence of the superiority of one text intervention over the other. Consequently, the refutation text may also represent a viable instructional method, particularly when supported with discussion activities (Guzzetti, 2000).

Another practical implication of the present study can be considered the development of a new personal epistemology instrument appropriate for upper elementary school students. Successive revision cycles resulted in a reliable, domain specific instrument that can be readily used for the assessment of elementary school students' personal epistemology in the domain of science.

Limitations of the study

The small duration of the interventions may have resulted in the small change observed in students' personal epistemology. Although the purpose of the study was to advance students' personal epistemology in science, the interventions were too short to generate advancement. The term advancement may require a robust and extensive change in students' personal epistemology. Such a process was not enabled in this study over the course of an 80 minute individual reading session. Rather, this study provided evidence of readiness for change. Future text-based instruction in personal epistemology could take findings of this study into account in organizing more extensive reading sessions to facilitate advancement.

Also, the length of the refutation and the analogy text was longer compared to the baseline text because these texts were rich in examples and explanations. As a result students in the refutation text and the analogy text groups were required to recall longer texts. This difference in text length may had generated a benefit for the students who read the baseline text preventing the manifestation of the anticipated substantial differences between the effectiveness of the two experimental texts (refutation and analogy) and the comparison text (baseline). Furthermore, the three texts used in this study were all cognitively demanding. Future research could take text difficulty into account in order to use shorter and more simplified versions of such texts on epistemological themes.

It should also be noted that although students were randomly allocated into the three text groups, no students with low text comprehension ability were assigned in the baseline text group. Again, this asymmetry may have provided an advantage for students in the baseline group. A larger sample could possibly help overcome this issue and could also increase statistical power.

Moreover, a ceiling effect observed in the analysis of the Personal Epistemology in Science Questionnaire (PESQ) may have precluded the accurate examination of the pattern of change for students who exhibited advanced epistemic stances over the course of the study. PESQ could be used in future research with the addition of more challenging items in order to provide more accurate information about students of all different levels of personal epistemology. Also, the overall low reliability of the implicit measurement of personal epistemology prevented the examination of the multidimensional structure in this facet of personal epistemology too. Alternative forms of assessment of this aspect of epistemology may be designed.

Suggestions for Future Research

The main goal of this study was to provide evidence that short-term instruction may advance personal epistemology. However, the study provided evidence that modest change in personal epistemology is feasible within the context of short-term instruction. Advancement requires more robust and extensive revisions in one's personal epistemology. Future research may examine the impact of more extensive reading sessions. For instance, a research design with four reading sessions would still be in accordance with the goal of short-term instruction.

The process of personal epistemology advancement that requires examination of one's belief stances on the nature of knowledge and knowing may entail some sort of critical thinking that involves a process of informed decision making (Bruning, Schraw, & Ronning, 1999). However, it is still an open question at which level personal epistemology operates and what are the interrelations with such higher-order thinking processes. There are studies, however, that provide support of the role of personal epistemology on self-regulation and metacognitive processes. Situated within a metacognitive architecture in our mind (Mason & Bromme, 2010) personal epistemology seems to shape thinking and learning by acting as an 'apprehension structure' (Bromme, Pieschl, & Stahl, 2010) which anticipates the task to be executed and helps learners adapt to the task by metacognitively calibrating to it. Personal epistemology may shape for instance, how critical thinking tasks should be approached. Further research may examine the impact of personal epistemology on critical thinking and may also explore how critical thinking may play a role in the process of personal epistemology advancement.

Conclusion

The underlying structure of personal epistemology of sixth grade students in science may be characterized as unidimensional possibly reflected in four interrelated dimensions (certainty, simplicity, source and justification). The personal epistemology of sixth grade students in science exhibits readiness for change as a function of instruction. Text-based approaches are viable instructional methods towards the advancement of personal epistemology.

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Appendices

Appendix A

Απόψεις για τη Γνώση και το Γνωρίζω στην Επιστήμη (Α)
ΜΕΡΟΣ Α

Όνομα: ____Τάξη: ______ Ημ..: ______

✍ΟΔΗΓΙΑ: ΔΙΑΒΑΣΕ ΠΑΡΑ ΠΟΛΥ ΠΡΟΣΕΚΤΙΚΑ ΤΗΝ ΚΑΘΕ ΔΗΛΩΣΗ ΚΑΙ ΣΗΜΕΙΩΣΕ ΕΑΝ ΣΥΜΦΩΝΕΙΣ Ή ΔΙΑΦΩΝΕΙΣ.

1. Οι επιστήμονες προσπαθούν κυρίως να αναφέρουν και να περιγράψουν όσα συμβαίνουν στη φύση, όπως μας αναφέρουν για παράδειγμα ότι οι πάγοι λιώνουν.	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
2.Οι γνώσεις στην επιστήμη αποτελούνται από απλά γεγονότα που είναι άσχετα μεταξύ τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
3. Από μόνες τους οι ιδέες των επιστημόνων, χωρίς κάποιο πείραμα δεν μπορούν να είναι νέα γνώση	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
4. Οι επιστήμονες ακολουθούν πάντα τον ίδιο τρόπο για να κάνουν τις έρευνές τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
5. Ένας λόγος για τον οποίο οι επιστήμονες κάνουν πειράματα είναι για να επιβεβαιώσουν τις θεωρίες που ήδη υπάρχουν, όπως π.χ. τη θεωρία που εξηγεί με ποιο τρόπο τα υγρά διαστέλλονται και συστέλλονται όταν αλλάζει η θερμοκρασία τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
6. Η διαδικασία για να γίνει μια έρευνα αλλάζει ανάλογα με το ερώτημα που χρειάζεται να απαντήσει ο επιστήμονας	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
7.Ένα ποίημα μπορεί να εξηγηθεί με διάφορους τρόπους αλλά δεν μπορεί να συμβαίνει το ίδιο με ένα φυσικό φαινόμενο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
8. Τα αποτελέσματα ενός πειράματος μιλούν από μόνα τους και δε χρειάζονται επεξηγήσεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
9. Η φύση είναι περίπλοκη και δε θα μπορέσουν ποτέ οι επιστήμονες να μάθουν με σιγουριά όλα τα μυστικά της	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
10. Δεν αρκεί ένας επιστήμονας να ξέρει καλά τις γνώσεις που ισχύουν σήμερα στην επιστήμη	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
11. Η απάντηση σε κάθε ερώτηση στην επιστήμη είναι μία και ξεκάθαρη	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
12. Εάν οι επιστήμονες προσπαθήσουν πολύ, μπορούν να βρουν την αλήθεια σχεδόν για όλα τα φαινόμενα που μελετούν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

13. Αν ένας επιστήμονας μπορεί να εξηγήσει με πειστικό τρόπο, χωρίς να κάνει κάποιο πείραμα μια νέα ιδέα που έχει, αυτό είναι αρκετό για να μας πείσει ότι η ιδέα του είναι σωστή	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
14. Δεν είναι παράξενο να ερωτηθούν επιστήμονες για ένα θέμα της ειδικότητάς τους και να δώσουν διαφορετικές απαντήσεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
15. Μια έξυπνη ιδέα ενός επιστήμονα μπορεί να γίνει θεωρία μόνο όταν φανεί ότι είναι σωστή μέσα από έρευνα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
16. Είναι τόσες πολλές οι γνώσεις στην επιστήμη σήμερα, που δεν μπορεί ένας επιστήμονας να κάνει νέες ανακαλύψεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
17. Οι επιστήμονες προσπαθούν να εξηγήσουν καλύτερα κάποια φαινόμενα που συμβαίνουν στη φύση. Έτσι, μπορεί να καταλήξουν στο συμπέρασμα ότι κάποια πράγματα που γνωρίζουμε μέχρι τώρα είναι λανθασμένα και χρειάζεται να αλλάξουν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
18. Αν τα αποτελέσματα του πειράματος δεν είναι αυτά που περίμενε ο επιστήμονας, τότε είναι άχρηστα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
19. Δεν μπορεί ένας επιστήμονας να κατεβάσει μια έξυπνη ιδέα και να πει ότι δημιούργησε μια νέα θεωρία	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
20. Είναι δυνατό τα αποτελέσματα ενός πειράματος να επεξηγηθούν με διαφορετικό τρόπο από διαφορετικούς επιστήμονες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
21. Μια θεωρία δημιουργείται όταν ένας επιστήμονας μαζέψει στοιχεία με έρευνα ή με πείραμα που να δείχνουν ότι η ιδέα που είχε μπορεί να εξηγήσει κάποιο φαινόμενο στη φύση	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
22. Ο σκοπός ενός επιστήμονα είναι να εξηγήσει μέσα από έρευνα με ποιο τρόπο λειτουργούν διάφορα φαινόμενα στη φύση, π.χ. γιατί λιώνουν οι πάγοι	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
23. Οι επιστήμονες δεν προσπαθούν μόνο να περιγράψουν φαινόμενα αλλά κυρίως να τα εξηγήσουν, δηλαδή να πουν πώς και γιατί συμβαίνουν κάποια πράγματα στον κόσμο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
24. Δεν αξίζει ένας επιστήμονας να δοκιμάζει σε πειράματα δικές του ιδέες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
25. Οι μετρήσεις που παίρνει ένας επιστήμονας από ένα πείραμα επιστήμης, αν είναι προσεκτικές οδηγούν σε συγκεκριμένα συμπεράσματα που δεν μπορεί να τα αμφισβητήσει κανείς	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

26. Για να μπορούν τα αποτελέσματα ενός πειράματος να απαντήσουν σε κάποιο ερώτημα στην επιστήμη, θα πρέπει να γίνει επεξήγησή τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
27. Ο τρόπος που θα κάνει μια έρευνα κάποιος επιστήμονας εξαρτάται από την ερώτηση που προσπαθεί να απαντήσει	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
28. Μέσα από ένα πείραμα μπορεί ένας επιστήμονας να συγκρίνει δύο θεωρίες για να δείξει ποια από τις δύο εξηγεί καλύτερα ένα φυσικό φαινόμενο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
29. Τα πειράματα των επιστημόνων σήμερα δεν μπορούν να αλλάξουν τις γνώσεις που αποκτήσαμε μέσα από τα πειράματα προηγούμενων χρόνων	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
30. Αν ένας επιστήμονας έχει μια έξυπνη ιδέα που μπορεί να εξηγήσει καλύτερα με ποιο τρόπο μπορούμε να κάνουμε εξοικονόμηση ενέργειας στα σπίτια μας, τότε δε χρειάζεται να κάνει κάποιο πείραμα ή να μαζέψει στοιχεία για να δείξει ότι η ιδέα του δουλεύει.	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
31. Οι διάφορες γνώσεις στην επιστήμη δεν είναι άσχετες μεταξύ τους. Πολλές φορές το ένα θέμα συνδέεται με το άλλο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
32. Η επιστημονική έρευνα απλά βοηθά να γίνουν περισσότερες οι γνώσεις μας για τη φύση	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
33. Νέες ανακαλύψεις μπορούν να αλλάξουν αυτά που πιστεύουν οι επιστήμονες ότι είναι η αλήθεια για ένα θέμα στην επιστήμη	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
34. Νέα γνώση στην επιστήμη δεν είναι τα αποτελέσματα ενός πειράματος αλλά τα συμπεράσματα που βγάζει ο επιστήμονας από τα αποτελέσματα του πειράματος	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
35. Είναι αρκετό για ένα επιστήμονα να ξέρει πολύ καλά τις γνώσεις που ισχύουν σήμερα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
36. Όταν μετά από πειράματα βγει ένα συμπέρασμα που εξηγεί καλύτερα π.χ. πώς οι κλιματικές αλλαγές επηρεάζουν τη μετανάστευση ζώων, τότε η γνώση μας για αυτό το φαινόμενο θα αλλάξει	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
37. Πολλές από τις ενότητες που υπάρχουν σε ένα βιβλίο επιστήμης, όπως π.χ. το βιβλίο επιστήμης του δημοτικού σχολείου, σχετίζονται μεταξύ τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

38. Σκοπός των επιστημόνων είναι μέσα από έρευνα να ανακαλύπτουν ολοένα και καλύτερα πώς και γιατί λειτουργούν διάφορα πράγματα στη φύση, π. χ. γιατί υπάρχει το φαινόμενο του θερμοκηπίου και τι αποτελέσματα έχει	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
39. Οι ιδέες στα βιβλία της επιστήμης κάποτε αλλάζουν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
40. Αν ένα πείραμα δείξει ότι η ιδέα που είχε ένας επιστήμονας ισχύει τότε κανείς δεν μπορεί να αμφισβητήσει την ιδέα του	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
41. Τα αποτελέσματα ενός πειράματος δεν είναι η μόνη αλήθεια για ένα φυσικό φαινόμενο όσο προσεκτικά και να γίνει το πείραμα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
42. Οι γνώσεις στην επιστήμη έχουν σχέση η μία με την άλλη	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
43. Είναι πολύ σημαντικό για ένα επιστήμονα να σχεδιάζει πειράματα για να ελέγξει αν ισχύουν οι νέες ιδέες που έχει	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
44. Τα βιβλία της επιστήμης παρουσιάζουν θεωρίες που έχουν επιβεβαιωθεί από τους επιστήμονες και δεν πρόκειται να αλλάξουν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
45. Αν ένας επιστήμονας κάνει πολύ προσεκτικά ένα πείραμα τότε μπορεί να ανακαλύψει την αλήθεια για το θέμα που μελετά	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
46. Νέα γνώση στην επιστήμη δεν είναι απλά τα αποτελέσματα ενός πειράματος αλλά ο τρόπος που επεξηγεί ο επιστήμονας τα αποτελέσματα του πειράματος	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
47. Μια ερώτηση στην επιστήμη μπορεί να έχει περισσότερες από μία διαφορετικές απαντήσεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
48. Αργά ή γρήγορα οι επιστήμονες θα ανακαλύψουν όλα τα μυστικά της φύσης	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

Απόψεις για τη Γνώση και το Γνωρίζω στην Επιστήμη (Β)
ΜΕΡΟΣ Α

Όνομα: ____Τάξη: ______ Ημ..: ______

✍ΟΔΗΓΙΑ: ΔΙΑΒΑΣΕ ΠΑΡΑ ΠΟΛΥ ΠΡΟΣΕΚΤΙΚΑ ΤΗΝ ΚΑΘΕ ΔΗΛΩΣΗ ΚΑΙ ΣΗΜΕΙΩΣΕ ΕΑΝ ΣΥΜΦΩΝΕΙΣ Ή ΔΙΑΦΩΝΕΙΣ.

1. Οι επιστήμονες φτάνουν στις ανακαλύψεις τους ακολουθώντας πολύ προσεκτικά κάποια γνωστά και συγκεκριμένα βήματα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
2. Στην επιστήμη είναι πολύ σημαντικά τα συμπεράσματα που βγαίνουν από τα αποτελέσματα ενός πειράματος	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
3. Σκοπός της επιστήμης είναι να δίνει απαντήσεις σε ερωτήματα όπως τι είναι το ηφαίστειο, τι είναι το λιώσιμο των πάγων, τι είναι ο ηλεκτρισμός, κλπ.	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
4. Τα αποτελέσματα οποιουδήποτε πειράματος μπορούν να αμφισβητηθούν, όσο προσεκτικά σχεδιασμένο κι αν είναι	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
5. Οι θεωρίες της επιστήμης είναι απλώς το καλύτερο για την ώρα αποτέλεσμα της προσπάθειας των επιστημόνων να εξηγήσουν τα φυσικά φαινόμενα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
6. Αν ένας επιστήμονας δεν πάρει τα αποτελέσματα που περίμενε από κάποιο πείραμα, τότε μπορεί να αλλάξει κάποια πράγματα στις ιδέες του και να το επαναλάβει	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
7. Είναι αρκετό για ένα επιστήμονα να εφαρμόζει τις μεθόδους που χρησιμοποιούνταν συνήθως στο παρελθόν από άλλους επιστήμονες της ειδικότητάς του	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
8. Ένας καλός επιστήμονας παίρνει ιδέες από τις γνώσεις που ισχύουν σήμερα για να κάνει νέες ανακαλύψεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
9. Οι γνώσεις στην επιστήμη είναι άσχετες μεταξύ τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
10. Είναι πιθανόν τα αποτελέσματα ενός πειράματος να σημαίνουν εντελώς διαφορετικά πράγματα για διαφορετικούς επιστήμονες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
11. Για να απαντήσει ένας επιστήμονας σε ένα επιστημονικό ερώτημα θα πρέπει να συνδυάσει πολλά κομμάτια γνώσης	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

12. Η δουλειά ενός επιστήμονα τελειώνει εκεί που τελειώνει και το πείραμα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
13. Οι νέες ιδέες που έχει ένας επιστήμονας ρέπει να ελεγχθούν μέσα από κάποιο πείραμα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
14. Αν ένας επιστήμονας δεν πήρε τα αποτελέσματα που περίμενε από κάποιο πείραμα και είναι βέβαιος ότι έκανε το πείραμα πάρα πολύ προσεκτικά, τότε αυτό ίσως να σημαίνει ότι χρειάζεται να αλλάξει τη θεωρία που χρησιμοποιεί για να απαντήσει τις ερωτήσεις που τον ενδιαφέρουν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
15. Αργά ή γρήγορα οι επιστήμονες θα ανακαλύψουν όλα τα μυστικά της φύσης	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
16. Μια ερώτηση στην επιστήμη μπορεί να έχει περισσότερες από μία διαφορετικές απαντήσεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
17. Αν ένας επιστήμονας μπορεί να μας παρουσιάσει μια ιδέα που έχει για την ανακύκλωση αλουμινίου τότε αυτό είναι αρκετό για να μας πείσει και δε χρειάζεται να κάνει πείραμα για να μας δείξει ότι κάτι καινούργιο έχει ανακαλυφθεί	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
18. Όταν ακούμε για νέες ανακαλύψεις στην επιστήμη θα πρέπει να ζητούμε να μάθουμε αν οι επιστήμονες στηρίζουν τις ιδέες τους με στοιχεία από κάποιο πείραμα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
19. Υπάρχουν επιστήμονες της ίδιας ειδικότητας που διαφωνούν μεταξύ τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
20. Για να δημιουργηθεί μια θεωρία χρειάζεται ο επιστήμονας να κάνει κάποια έρευνα ή κάποιο πείραμα με σκοπό να μαζέψει στοιχεία που να στηρίζουν κάποια ιδέα που είχε	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
21. Ένας πίνακας ζωγραφικής μπορεί να εξηγηθεί με διάφορους τρόπους αλλά δεν μπορεί να συμβαίνει το ίδιο με ένα φυσικό	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
22. Στόχος της επιστήμης είναι να περιγράψει τα διάφορα φαινόμενα που συμβαίνουν όπως το λιώσιμο των πάγων, η εξαφάνιση διαφόρων ειδών ζώων και φυτών στον πλανήτη, η ύπαρξη ασθενειών κλπ	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
23. Γνωρίζουμε τόσα πολλά στην επιστήμη στις μέρες μας που είναι δύσκολο να γίνουν νέες ανακαλύψεις	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
24. Νέα γνώση στην επιστήμη είναι τα αποτελέσματα ενός πειράματος και όχι η επεξήγησή τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

25. Ένας καλός επιστήμονας ελέγχει νέες ιδέες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
26. Νέα γνώση στην επιστήμη δεν είναι απλά τα αποτελέσματα ενός πειράματος αλλά ο τρόπος που επεξηγεί ο επιστήμονας τα αποτελέσματα του πειράματος	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
27. Τα στοιχεία που μπορεί να μαζέψει ένας επιστήμονας μπορεί να μη στηρίζουν την ιδέα που είχε	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
28. Αν ένας επιστήμονας κάνει πολύ προσεκτικά ένα πείραμα τότε μπορεί να ανακαλύψει την αλήθεια για το θέμα που μελετά	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
29.Μια θεωρία στην επιστήμη θα πρέπει να βελτιώνεται ή ακόμα και να απορρίπτεται όταν δεν μπορεί να επαληθευθεί μέσα από προσεκτικά πειράματα που επαναλαμβάνονται συνεχώς και δείχνουν τα ίδια αποτελέσματα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
30. Αν ένα πείραμα έγινε πολύ προσεκτικά τότε κανείς δεν μπορεί να αμφισβητήσει τα αποτελέσματά του	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
31. Δεν είναι απαραίτητο οι επιστήμονες να εφαρμόζουν νέους τρόπους για να ελέγχουν τις ιδέες τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
32.Η έρευνα στην επιστήμη μπορεί να βοηθήσει να καταλάβουμε καλύτερα πώς λειτουργεί ο ανθρώπινος εγκέφαλος	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
33.Τα αποτελέσματα ενός πειράματος μπορούν να αμφισβητηθούν από τα αποτελέσματα άλλου πειράματος που να δείχνουν το αντίθετο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
34. Η επιστημονική έρευνα δε θα αλλάξει τα όσα γνωρίζαμε για τον ανθρώπινο εγκέφαλο μέχρι τώρα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
35. Ο κάθε επιστήμονας επεξηγεί τα αποτελέσματα ενός πειράματος σύμφωνα με τις δικές του ιδέες και θεωρίες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
36. Οι επιστήμονες θα καταφέρουν κάποτε να βρουν όλες τις απαντήσεις για το πώς λειτουργεί ο φυσικός κόσμος	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
37. Τα βιβλία της επιστήμης παρουσιάζουν θεωρίες που έχουν επιβεβαιωθεί από τους επιστήμονες και δεν πρόκειται να αλλάξουν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
38. Αν ένας επιστήμονας πάρει αποτελέσματα από ένα πείραμα που δεν τα περίμενε τότε αυτό σημαίνει ότι δεν έκανε και πολύ προσεκτικά το πείραμα	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

39. Πολλές από τις θεωρίες που ισχύουν σήμερα στην επιστήμη είναι πιθανόν στο μέλλον να αλλάξουν	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
40. Οι γνώσεις στην επιστήμη μοιάζουν με τον ιστό της αράχνης όπου το κάθε μέρος του ιστού σχετίζεται με πολλά άλλα μέρη του	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
41. Σκοπός της επιστήμης είναι να εξηγήσει διάφορα φαινόμενα, π.χ. γιατί συμβαίνουν και με ποιο τρόπο συμβαίνουν οι σεισμοί	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
42. Κάποιες ιδέες στην επιστήμη σήμερα είναι διαφορετικές από εκείνες που πίστευαν παλιά οι επιστήμονες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
43. Οι έξυπνες ιδέες που έχουν οι επιστήμονες λέγονται θεωρίες	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
44. Οι γνώσεις στην επιστήμη σχετίζονται μεταξύ τους	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
45. Δεν αξίζει ένας επιστήμονας να δοκιμάζει σε πειράματα δικές του ιδέες.	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
46. Οι επιστήμονες δεν προσπαθούν μόνο να περιγράψουν φαινόμενα αλλά κυρίως να τα εξηγήσουν, δηλαδή να πουν πώς και γιατί συμβαίνουν κάποια πράγματα στον κόσμο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
47. Ο τρόπος που θα κάνει μια έρευνα κάποιος επιστήμονας εξαρτάται από την ερώτηση που προσπαθεί να απαντήσει	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
48. Αν ένας επιστήμονας έχει μια έξυπνη ιδέα που μπορεί να εξηγήσει καλύτερα με ποιο τρόπο μπορούμε να κάνουμε εξοικονόμηση ενέργειας στα σπίτια μας, τότε δε χρειάζεται να κάνει κάποιο πείραμα ή να μαζέψει στοιχεία για να δείξει ότι η ιδέα του δουλεύει.	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ
49. Οι διάφορες γνώσεις στην επιστήμη δεν είναι άσχετες μεταξύ τους. Πολλές φορές το ένα θέμα συνδέεται με το άλλο	ΣΥΜΦΩΝΩ	ΔΙΑΦΩΝΩ

Appendix B

Απόψεις για τη Γνώση και το Γνωρίζω στην Επιστήμη (Α)
ΜΕΡΟΣ Β

Όνομα: ____Τάξη: ______ Ημ..:

✍ΟΔΗΓΙΑ: ΔΥΟ ΠΑΙΔΙΑ ΔΙΑΦΩΝΟΥΝ ΓΙΑ ΕΝΑ ΘΕΜΑ ΣΧΕΤΙΚΟ ΜΕ ΤΗΝ ΕΠΙΣΤΗΜΗ. ΔΙΑΒΑΣΕ ΠΡΟΣΕΚΤΙΚΑ ΤΗΝ ΚΟΥΒΕΝΤΑ ΤΩΝ ΠΑΙΔΙΩΝ ΚΑΙ ΣΗΜΕΙΩΣΕ ΑΠΟ ΚΑΤΩ ΜΕ ΠΟΙΟ ΠΑΙΔΙ ΣΥΜΦΩΝΕΙΣ ΠΕΡΙΣΣΟΤΕΡΟ.

1. Η Μαρία και η Άντρη διαφωνούν για τη δουλειά των επιστημόνων
Μαρία*: Πιστεύω ότι η φύση είναι τόσο περίπλοκη και υπάρχουν τόσο φυσικά φαινόμενα για να εξερευνήσει ένας επιστήμονας. Η δουλειά των επιστημόνων όμως είναι να γνωρίσουν σιγά-σιγά όλα τα φυσικά φαινόμενα.*
Άντρη*: Διαφωνώ. Δε νομίζω ότι οι επιστήμονες απλά προσπαθούν να μας δώσουν μια εικόνα του κόσμου. Υπάρχουν πράγματα στη φύση για τα οποία δεν μπορείς με μια απλή ματιά να καταλάβεις τι συμβαίνει και γιατί. Δουλειά των επιστημόνων είναι να εξηγήσουν γιατί συμβαίνουν κάποια φαινόμενα όπως π.χ. γιατί όταν κυλήσεις μια μπάλα στο έδαφος και δεν την ξαναγγίξεις σε κάποια φάση θα σταματήσει.*
Μαρία*: Δουλειά τους είναι να πουν ότι η μπάλα θα σταματήσει και όχι γιατί θα σταματήσει.*

Α. Συμφωνώ απολύτως με τη Μαρία
Β. Αν και συμφωνώ περισσότερο με την Μαρία νομίζω ότι και η Άντρη έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με την Άντρη νομίζω ότι και η Μαρία έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με την Άντρη

2. Ο Χρίστος και ο Σωτήρης έχουν μια διαφωνία για το ποιος είναι ένας καλός επιστήμονας:

Χρίστος: *Ένας επιστήμονας μπορεί να ξέρει πάρα πολλά, αλλά για να καταλήξει σε μια θεωρία θα πρέπει να έχει μία καλή ιδέα και για να δει πόσο καλή είναι θα πρέπει να κάνει έρευνα, δηλαδή να μαζέψει πληροφορίες με διάφορους τρόπους ή να κάνει κάποιο πείραμα. Από τα αποτελέσματα που θα έχει μπορεί να σκεφτεί μια νέα θεωρία ή μπορεί να βοηθήσει ώστε άλλες θεωρίες να αλλάξουν και να γίνουν καλύτερες.*

Σωτήρης: *Διαφωνώ. Πιστεύω πως καλός είναι ο επιστήμονας που διάβασε τόσο πολύ ώστε ξέρει σχεδόν τα πάντα για τη φύση και τον κόσμο. Έτσι κάθε νέα ιδέα που έχει μπορεί να είναι και μια θεωρία. Όταν κάποιος είναι διαβασμένος ξέρει τι λέει και δε χρειάζεται έρευνα για να τον βοηθήσει να βρει μια θεωρία. Όλα εκείνα που διάβασε είναι αρκετά.*

Χρίστος: *Η έρευνα είναι απαραίτητη*

Α. Συμφωνώ απολύτως με το Χρίστο
Β. Αν και συμφωνώ περισσότερο με τον Χρίστο νομίζω ότι και ο Σωτήρης έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με το Σωτήρη νομίζω ότι και ο Χρίστος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με το Σωτήρη

3. Ο Γιάννης και ο Αντώνης διαφωνούν για τη γνώση στην επιστήμη

Γιάννης: *Νομίζω ότι οι επιστήμονες κάνουν νέα πειράματα αλλά πιστεύω ότι σε κάποια φάση αυτό θα σταματήσει. Δεν μπορούν να ερευνούν για πάντα. Ο κόσμος είναι ένας και σε κάποια στιγμή θα έχουν καταγράψει όλα τα φυσικά φαινόμενα που υπάρχουν.*

Αντώνης: *Δε συμφωνώ με αυτά που λες. Οι επιστήμονες δεν καταγράφουν απλά διάφορα φαινόμενα κι έτσι η δουλειά τους δεν τελειώνει με αυτό. Συνεχώς προσπαθούν να εξηγήσουν με ολοένα και καλύτερο τρόπο τα διάφορα φαινόμενα στη φύση. Μπορεί παλαιότερα π.χ. να είχαν εξηγήσει οι επιστήμονες γιατί συμβαίνει το φαινόμενο του θερμοκηπίου αλλά τώρα προσπαθούν να ανακαλύψουν με ποιο τρόπο μπορούν να αντιμετωπίσουν αυτό το πρόβλημα.*

Γιάννης: *Εγώ πάλι πιστεύω ότι δε χρειάζεται να ασχολούνται με θέματα που ασχολήθηκαν ήδη άλλοι επιστήμονες. Μόνο έτσι θα πάμε μπροστά. Ό,τι ανακαλύφθηκε είναι σίγουρο και δεν μπορεί να αλλάξει. Άρα γιατί οι επιστήμονες να ασχολούνται με όσα ξέρουμε ότι είναι αλήθεια;*

Α. Συμφωνώ απολύτως με το Γιάννη
Β. Αν και συμφωνώ περισσότερο με το Γιάννη νομίζω ότι και ο Αντώνης έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Αντώνη νομίζω ότι και ο Γιάννης έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τον Αντώνη

4. Η Έλενα και η Δώρα διαφωνούν:

Έλενα: *Πώς είναι δυνατόν για ένα επιστήμονα στις μέρες μας να κάνει νέες ανακαλύψεις; Είναι τόσα πολλά όλα αυτά που γνωρίζουν ήδη οι επιστήμονες που είναι αδύνατο! Το μόνο που μπορεί να πετύχει ένας επιστήμονας σήμερα είναι να δείξει μέσα από τη δουλειά του ότι οι γνώσεις που ανακάλυψαν άλλοι επιστήμονες πριν από αυτόν ισχύουν ακόμα.*

Δώρα: *Διαφωνώ με αυτό που λες. Και πού βάζεις τις νέες ιδέες που μπορεί να έχει ένας επιστήμονας; Με βάση όσα είναι γνωστά, ένας καλός επιστήμονας σκέφτεται νέα πράγματα που μπορεί να οδηγήσουν σε νέες ανακαλύψεις! Οι ιδέες των επιστημόνων βοηθούν να εξελίσσεται η γνώση*

Έλενα: *Δεν πιστεύω ότι μπορούν να υπάρξουν νέες ανακαλύψεις.*

Α. Συμφωνώ απολύτως με την Έλενα
Β. Αν και συμφωνώ περισσότερο με την Έλενα νομίζω ότι και η Δώρα έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Δώρα νομίζω ότι και η Έλενα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Δώρα

5. Μάρθα και η Σοφία διαφωνούν όπως φαίνεται πιο κάτω:

Μάρθα: *Παρακολουθούσα τις ειδήσεις πριν λίγες μέρες και μου έκανε μεγάλη εντύπωση που δύο επιστήμονες διαφωνούσαν για ένα εμβόλιο κατά της γρίπης! Δεν μπορούσαν να συμφωνήσουν για το αν το εμβόλιο κάνει καλό ή όχι!*

Σοφία: *Σε εμένα δε φαίνεται και πολύ παράξενο αυτό που λες. Συμβαίνει πολύ συχνά οι επιστήμονες να διαφωνούν για ένα θέμα. Αυτό συμβαίνει γιατί οι ιδέες τους και οι θεωρίες που υποστηρίζουν είναι διαφορετικές.*

Μάρθα: *Ναι, αλλά θα πρέπει να μπορούν να συμφωνήσουν αν κάτι είναι σωστό ή όχι, όσο διαφορετικές ιδέες κι αν έχουν.*

Α. Συμφωνώ απολύτως με τη Μάρθα
Β. Αν και συμφωνώ περισσότερο με τη Μάρθα νομίζω ότι και η Σοφία έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Σοφία νομίζω ότι και η Μάρθα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Σοφία

6. Ο Στέφανος και ο Μάριος κάνουν μια συζήτηση για τις γνώσεις στην επιστήμη
Στέφανος: *Κάθε καινούργια γνώση στην επιστήμη συνδέεται με τα όσα γνωρίζουν οι επιστήμονες μέχρι εκείνη τη στιγμή. Άρα δεν πρέπει συνέχεια απλά να προσθέτουν σε αυτά που ξέρουν. Πολλές φορές όταν ανακαλυφθεί κάτι καινούργιο οι επιστήμονες μπορεί να χρειάζεται να αλλάξουν τα όσα ήξεραν μέχρι εκείνη τη στιγμή*
Μάριος: *Διαφωνώ με αυτό που λες. Δεν πιστεύω ότι οι γνώσεις στην επιστήμη συνδέονται τόσο πολύ μεταξύ τους.*
Κάθε διαφορετική ανακάλυψη ή κάθε διαφορετικό θέμα προστίθεται σε όλα τα υπόλοιπα που γνωρίζουν οι επιστήμονες μέχρι εκείνη τη στιγμή. Κάθε επιστήμονας θα πρέπει να είναι μια κινητή βιβλιοθήκη!
Στέφανος*: Α μπα! Αδύνατο ακούγεται αυτό που λες!*

Α. Συμφωνώ απολύτως με το Στέφανο
Β. Αν και συμφωνώ περισσότερο με το Στέφανο νομίζω ότι και ο Μάριος έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με το Μάριο νομίζω ότι και ο Στέφανος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με το Μάριο

7. Ο Βασίλης και ο Τάσος διαφωνούν για την αλήθεια στην επιστήμη
Βασίλης*: Όσες έρευνες και να γίνουν στον κόσμο οι επιστήμονες δε θα ανακαλύψουν ποτέ την απόλυτη αλήθεια για κάθε φυσικό φαινόμενο. Αυτό που θα κάνουν όμως είναι να καταφέρουν να κατανοήσουν και να εξηγήσουν καλύτερα κάποια φαινόμενα.*
Τάσος: *Διαφωνώ με αυτό που λες. Γίνονται τόσες έρευνες από τους επιστήμονες που είμαι σίγουρος ότι σύντομα θα ξέρουμε την απόλυτη αλήθεια για όλα τα φυσικά φαινόμενα. Θα ξέρουμε δηλαδή τα πάντα και με σιγουριά για όλα τα φυσικά φαινόμενα. Διαφορετικά δεν έχει αξία η έρευνα που κάνουν οι επιστήμονες.*
Βασίλης: *Όσα και να γνωρίζουν οι επιστήμονες πάντα θα ανακαλύπτουν νέα πράγματα. Δεν υπάρχει απόλυτη αλήθεια.*

Α. Συμφωνώ απολύτως με το Βασίλη
Β. Αν και συμφωνώ περισσότερο με το Βασίλη νομίζω ότι και ο Τάσος έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Τάσο νομίζω ότι και ο Βασίλης έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τον Τάσο

8. Η Μαίρη και η Άννα διαφωνούν για την εξαφάνιση των δεινοσαύρων:

Μαίρη: *Μερικοί επιστήμονες υποστηρίζουν ότι οι δεινόσαυροι εξαφανίστηκαν όταν ένας αστεροειδής χτύπησε τη γη, ενώ άλλοι ισχυρίζονται ότι η εξαφάνισή τους οφείλεται σε εκρήξεις ηφαιστείων. Δεν καταλαβαίνω γιατί δεν μπορούν να συμφωνήσουν.*

Άννα: *Νομίζω ότι δεν υπάρχει μόνο ένας τρόπος να εξηγήσεις τα διάφορα γεγονότα. Οι επιστήμονες προσπαθούν συνεχώς να βρουν τον καλύτερο τρόπο για να εξηγήσουν κάποιο γεγονός ή φαινόμενο. Έτσι υπάρχουν διάφορες θεωρίες για το πώς εξαφανίστηκαν οι δεινόσαυροι*

Μαίρη: *Αυτό το καταλαβαίνω αν μιλάμε π.χ. για τις σχέσεις των ανθρώπων. Εκεί τα πράγματα δεν είναι τόσο ξεκάθαρα. Αλλά στην επιστήμη τα γεγονότα μιλάνε από μόνα τους*

Α. Συμφωνώ απολύτως με τη Μαίρη
Β. Αν και συμφωνώ περισσότερο με τη Μαίρη νομίζω ότι και η Άννα έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με την Άννα νομίζω ότι και η Μαίρη έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με την Άννα

9. Η Αλεξάνδρα και η Δανάη διαφωνούν όπως φαίνεται παρακάτω:

Αλεξάνδρα: *Τα πειράματα βοηθούν τους επιστήμονες να βρουν μια θεωρία.*

Δανάη: *Εγώ αντίθετα νομίζω ότι τα πειράματα βοηθούν τους επιστήμονες να διαλέξουν την καλύτερη ανάμεσα σε διάφορες θεωρίες.*

Αλεξάνδρα: *Διαφωνώ. Ένα πείραμα πρέπει να σχετίζεται μόνο μια θεωρία.*

Α. Συμφωνώ απολύτως με την Αλεξάνδρα
Β. Αν και συμφωνώ περισσότερο με την Αλεξάνδρα νομίζω ότι και η Δανάη έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Δανάη νομίζω ότι και η Αλεξάνδρα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Δανάη

10. Χρίστος και ο Αλέκος συζητούν και διαφωνούν:
Χρίστος: *Τα αποτελέσματα του πειράματος είναι σημαντικά. Αλλά η δουλειά του επιστήμονα δεν τελειώνει ως εκεί. Ο τρόπος που θα εξηγήσει τα αποτελέσματα και θα βγάλει συμπεράσματα είναι πάρα πολύ σημαντικός. Ένας επιστήμονας χρησιμοποιεί τα αποτελέσματα για να βγάλει συμπεράσματα.*
Αλέκος: *Διαφωνώ. Η δουλειά του επιστήμονα τελειώνει εκεί που τελειώνει και το πείραμα. Δηλαδή τα αποτελέσματα του πειράματος είναι εκείνο που χρειάζεται για να τελειώσει τη δουλειά του. Δε νομίζω τα αποτελέσματα να διαφέρουν και πολύ από τα συμπεράσματα.*
Χρίστος*: Η σημασία του πειράματος βρίσκεται στα συμπεράσματα που θα βγάλει ο επιστήμονας.*

Α. Συμφωνώ απολύτως με το Χρίστο
Β. Αν και συμφωνώ περισσότερο με το Χρίστο νομίζω ότι και ο Αλέκος έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Αλέκο νομίζω ότι και ο Χρίστος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τον Αλέκο

11. Η Κατερίνα και η Γεωργία διαφωνούν:
Κατερίνα: *Δεν υπάρχει μόνο ένας τρόπος για να γίνει κάποιο πείραμα. Σύμφωνα με την ερώτηση που προσπαθεί να απαντήσει ο επιστήμονας αλλάζει και ο τρόπος που θα κάνει το πείραμα.*
Γεωργία: *Διαφωνώ. Η γνώμη μου είναι πως όποια ερώτηση και να θέλει να απαντήσει ένας επιστήμονας ακολουθεί πάντα την ίδια πορεία και διαδικασία. Δηλαδή τα βήματα που πρέπει να ακολουθήσει είναι γνωστά.*
Κατερίνα: *Το είδος του πειράματος εξαρτάται από την ερώτηση που βάζει ο επιστήμονας*

Α. Συμφωνώ απολύτως με την Κατερίνα
Β. Αν και συμφωνώ περισσότερο με την Κατερίνα νομίζω ότι και η Γεωργία έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Γεωργία νομίζω ότι και η Κατερίνα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Γεωργία

12. Ο Μάριος και ο Αλέξης διαφωνούν:

Μάριος: *Νομίζω ότι η δουλειά που κάνουν οι επιστήμονες είναι εύκολη αν σκεφτείς ότι ακολουθούν τον τρόπο που χρησιμοποιούσαν και άλλοι επιστήμονες πριν από αυτούς*

Αλέξης: *Διαφωνώ απόλυτα με αυτό που λες. Τα πειράματα δε γίνονται πάντα με τον ίδιο τρόπο. Ένας καλός επιστήμονας ξέρει να αλλάζει τον τρόπο που θα κάνει ένα πείραμα ανάλογα με την ερώτηση που έχει να απαντήσει. Πρέπει να μπορεί να σκέφτεται νέους τρόπους για να κάνει τα πειράματά του. Μόνο έτσι μπορεί να προχωρήσει μπροστά.*

Μάριος: *Εγώ πιστεύω πως το πιο σωστό είναι να ακολουθεί τους τρόπους που ακολουθούσαν και οι επιστήμονες πριν από αυτόν. Μόνο έτσι δε θα κάνει λάθη.*

Α. Συμφωνώ απολύτως με το Μάριο
Β. Αν και συμφωνώ περισσότερο με το Μάριο νομίζω ότι και ο Αλέξης έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Αλέξη νομίζω ότι και ο Μάριος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με το Αλέξη

13. Η Χαρά και η Εύη διαφωνούν για τη γνώση στην επιστήμη

Χαρά: *Η επιστήμη μοιάζει κάπως με τη μόδα: κάτι που είναι στη μόδα τη μια χρόνια, μπορεί να μην είναι στη μόδα την επόμενη χρονιά. Οι επιστήμονες αλλάζουν τις θεωρίες τους κάποτε προς κάτι νέο κάποτε προς κάτι που ήταν ήδη γνωστό από πριν.*

Εύη: *Διαφωνώ. Πιστεύω ότι όταν γίνουν κάποια πειράματα και με βάση τα αποτελέσματά τους δημιουργηθούν θεωρίες τότε οι θεωρίες ισχύουν και το θέμα έχει κλείσει. Δεν υπάρχει λόγος για άλλη συζήτηση. Δε νομίζω ότι μπορεί η γνώση στην επιστήμη να αλλάζει.*

Χαρά: Η γνώση μπορεί να αλλάξει μέσα από την έρευνα που κάνουν οι επιστήμονες

Α. Συμφωνώ απολύτως με τη Χαρά
Β. Αν και συμφωνώ περισσότερο με τη Χαρά νομίζω ότι και η Εύη έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με την Εύη νομίζω ότι και η Χαρά έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με την Εύη

Απόψεις για τη Γνώση και το Γνωρίζω στην Επιστήμη (Β)
ΜΕΡΟΣ Β

Όνομα: ____Τάξη: ______ Ημ..:

✍ΟΔΗΓΙΑ: ΔΥΟ ΠΑΙΔΙΑ ΔΙΑΦΩΝΟΥΝ ΓΙΑ ΕΝΑ ΘΕΜΑ ΣΧΕΤΙΚΟ ΜΕ ΤΗΝ ΕΠΙΣΤΗΜΗ. ΔΙΑΒΑΣΕ ΠΡΟΣΕΚΤΙΚΑ ΤΗΝ ΚΟΥΒΕΝΤΑ ΤΩΝ ΠΑΙΔΙΩΝ ΚΑΙ ΣΗΜΕΙΩΣΕ ΑΠΟ ΚΑΤΩ ΜΕ ΠΟΙΟ ΠΑΙΔΙ ΣΥΜΦΩΝΕΙΣ ΠΕΡΙΣΣΟΤΕΡΟ.

1. Ο Μάριος και ο Αλέξης διαφωνούν:
Μάριος: *Νομίζω ότι η δουλειά που κάνουν οι επιστήμονες είναι εύκολη αν σκεφτείς ότι ακολουθούν τον τρόπο που χρησιμοποιούσαν και άλλοι επιστήμονες πριν από αυτούς*
Αλέξης: *Διαφωνώ απόλυτα με αυτό που λες. Τα πειράματα δε γίνονται πάντα με τον ίδιο τρόπο. Ένας καλός επιστήμονας ξέρει να αλλάζει τον τρόπο που θα κάνει ένα πείραμα ανάλογα με την ερώτηση που έχει να απαντήσει. Πρέπει να μπορεί να σκέφτεται νέους τρόπους για να κάνει τα πειράματά του. Μόνο έτσι μπορεί να προχωρήσει μπροστά.*
Μάριος: *Εγώ πιστεύω πως το πιο σωστό είναι να ακολουθεί τους τρόπους που ακολουθούσαν και οι επιστήμονες πριν από αυτόν. Μόνο έτσι δε θα κάνει λάθη.*

Α. Συμφωνώ απολύτως με το Μάριο
Β. Αν και συμφωνώ περισσότερο με το Μάριο νομίζω ότι και ο Αλέξης έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Αλέξη νομίζω ότι και ο Μάριος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με το Αλέξη

2. Ο Πέτρος και ο Μάνος διαφωνούν:
Πέτρος: *Υπάρχουν πολλές θεωρίες που εξηγούν το ίδιο θέμα στην επιστήμη με διαφορετικό τρόπο. Έτσι και οι επιστήμονες μπορεί να πιστεύουν σε διαφορετικές θεωρίες για τα θέματα της ειδικότητάς τους. Αυτό τους κάνει να εξηγούν τα αποτελέσματα ακόμα και του ίδιου πειράματος με διαφορετικό τρόπο και να βγάζουν διαφορετικά συμπεράσματα.*
Μάνος: *Διαφωνώ με αυτό που λες. Πιστεύω πως όταν γίνει ένα πείραμα στην επιστήμη πολύ προσεκτικά τότε θα πρέπει λογικά να μπορούν όλοι οι επιστήμονες που είναι ειδικοί στο θέμα του πειράματος να συμφωνήσουν για το τι σημαίνουν τα αποτελέσματα του πειράματος. Θα έπρεπε για το ίδιο θέμα, εφόσον είναι ειδικοί, να μπορούν να συμφωνήσουν.*
Πέτρος: *Οι σκέψεις και οι απόψεις του κάθε επιστήμονα είναι διαφορετικές*

Α. Συμφωνώ απολύτως με τον Πέτρο
Β. Αν και συμφωνώ περισσότερο με τον Πέτρο νομίζω ότι και ο Μάνος έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με το Μάνο νομίζω ότι και ο Πέτρος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με το Μάνο

3. Η Δάφνη και η Μυρτώ διαφωνούν για την αλήθεια στην επιστήμη
Δάφνη: *Με τα πειράματά τους οι επιστήμονες ανακαλύπτουν την αλήθεια για τα φαινόμενα που μελετούν και κανείς δεν μπορεί να τα αμφισβητήσει.*
Μυρτώ: *Μπορεί να είναι σημαντικά τα αποτελέσματα των πειραμάτων τους αλλά με αυτά δεν ανακαλύπτουν την απόλυτη αλήθεια. Απλά τα αποτελέσματα τους βοηθούν να κατανοήσουν καλύτερα τα φυσικά φαινόμενα που μελετούν. Ποτέ όμως δε θα μπορέσουμε να πούμε ότι ανακάλυψαν τα πάντα για ένα φαινόμενο και ότι δε χρειάζεται να ερευνηθεί άλλο.*
Δάφνη: *Διαφωνώ. Αυτό που λες κάνει τη δουλειά των επιστημόνων να ακούγεται ασήμαντη αφού δεν μπορεί να φτάσει στην απόλυτη αλήθεια.*

Α. Συμφωνώ απολύτως με τη Δάφνη
Β. Αν και συμφωνώ περισσότερο με τη Δάφνη νομίζω ότι και η Μυρτώ έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με την Μυρτώ νομίζω ότι και η Δάφνη έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Μυρτώ

4. Ο Πάνος και ο Δώρος διαφωνούν:
Δώρος: *Δεν υπάρχουν σωστές και λάθος θεωρίες. Ένα πείραμα μπορεί να δείξει αν μια θεωρία μπορεί να εξηγήσει ένα φαινόμενο καλύτερα από κάποια άλλη θεωρία.*
Πάνος: *Το πείραμα δε συγκρίνει θεωρίες. Δείχνει αν μια θεωρία είναι σωστή. Από τη στιγμή που υπάρχει μια θεωρία τότε αυτό είναι και η αλήθεια για ένα φυσικό φαινόμενο. Άρα δεν μπορούν να υπάρχουν άλλες θεωρίες για το ίδιο θέμα.*
Δώρος: *Κι όμως ένα πείραμα μπορεί να μας δείξει ποια θεωρία μπορεί να εξηγήσει καλύτερα κάποιο φαινόμενο*

Α. Συμφωνώ απολύτως με το Δώρο
Β. Αν και συμφωνώ περισσότερο με το Δώρο νομίζω ότι και ο Πάνος έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Πάνο νομίζω ότι και ο Δώρος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τον Πάνο

5. Η Μαρία και η Χριστίνα έχουν διαφορετική άποψη για τη δουλειά των επιστημόνων
Μαρία: *Οι επιστήμονες σκέφτονται κάποια ερωτήματα. Για να τα απαντήσουν κάνουν έρευνες ή πειράματα και καταλήγουν σε κάποια συμπεράσματα. Όταν συσχετίσουν αυτά τα συμπεράσματα με τα όσα γνωρίζουν μέχρι εκείνη τη στιγμή καταλήγουν σε κάποιες θεωρίες.*
Χριστίνα: *Εγώ πάλι δεν πιστεύω ότι χρειάζεται τόσος κόπος για να βγάλει ένας επιστήμονας μία θεωρία*
Οι επιστήμονες σκέφτονται ένα θέμα που τους ενδιαφέρει και αφού κάνουν κάποιες σκέψεις βγάζουν και μια θεωρία. Η έρευνα και το πείραμα δεν είναι απαραίτητα
Μαρία*: Δεν είναι τόσο απλό για ένα επιστήμονα να βγάλει μια θεωρία.*

Α. Συμφωνώ απολύτως με τη Μαρία
Β. Αν και συμφωνώ περισσότερο με τη Μαρία νομίζω ότι και η Χριστίνα έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Χριστίνα νομίζω ότι και η Μαρία έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Χριστίνα

6. Η Σταυρούλα και η Νίκη διαφωνούν:
Σταυρούλα: *Προτού οι επιστήμονες κάνουν κάποια πειράματα συνήθως κάνουν προβλέψεις για τα αποτελέσματα. Όμως αν τα αποτελέσματα δεν είναι εκείνα που περίμεναν τότε τα αποτελέσματα είναι άχρηστα και πρέπει να ξαναρχίσουν από την αρχή.*
Νίκη*: Όχι, αυτό που λες δεν είναι αλήθεια. Κάποιες φορές τα αποτελέσματα είναι εκείνα που περίμεναν και κάποτε όχι. Αν πάρουν αποτελέσματα που δεν περίμεναν, τότε προσπαθούν να καταλάβουν για ποιο λόγο πήραν τέτοια αποτελέσματα και να βγάλουν κάποια συμπεράσματα. Άλλες φορές πάλι μπορεί να χρειαστεί να σκεφτούν αν οι ερωτήσεις που θέλουν να απαντήσουν χρειάζεται να αλλάξουν και να ξανακάνουν το πείραμα.*
Σταυρούλα: *Δεν πιστεύω πως αν κάνουν το πείραμα πολύ προσεκτικά με τον τρόπο που πρέπει χρειάζεται να μάθουν για ποιο λόγο τα αποτελέσματα είναι διαφορετικά από αυτά που περίμεναν. Απλά τα αποτελέσματα είναι άχρηστα.*

Α. Συμφωνώ απολύτως με τη Σταυρούλα
Β. Αν και συμφωνώ περισσότερο με τη Σταυρούλα νομίζω ότι και η Νίκη έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Νίκη νομίζω ότι και η Σταυρούλα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Νίκη

7. Η Χριστίνα και η Αμαλία διαφωνούν:
Χριστίνα: *Πιστεύω ότι η νέα γνώση στην επιστήμη δημιουργείται από τη στιγμή που ο επιστήμονας παίρνει στα χέρια του τα αποτελέσματα του πειράματος που σχεδίασε.*
Αμαλία: *Διαφωνώ. Η νέα γνώση δε είναι τα αποτελέσματα από μόνα τους, αλλά ο τρόπος που ο επιστήμονας εξηγεί αυτά τα αποτελέσματα και βγάζει συμπεράσματα.*
Χριστίνα: *Τα αποτελέσματα του πειράματος δεν μπορούν να αμφισβητηθούν και έτσι αυτό είναι η νέα γνώση, όχι τα συμπεράσματα του επιστήμονα.*

Α. Συμφωνώ απολύτως με τη Χριστίνα
Β. Αν και συμφωνώ περισσότερο με τη Χριστίνα νομίζω ότι και η Αμαλία έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με την Αμαλία νομίζω ότι και η Χριστίνα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με την Αμαλία

8. Ο Γιώργος και ο Αντώνης διαφωνούν για το σκοπό της επιστήμης
Γιώργος: *Πιστεύω ότι η δουλειά των επιστημόνων δεν είναι απλά να περιγράφουν φαινόμενα αλλά να τα επεξηγούν. Να μπορούν π.χ. να πουν τι είναι οι σεισμοί αλλά να μπορούν να πουν και γιατί δημιουργούνται.*
Αντώνης: *Διαφωνώ. Πιστεύω πως δουλειά των επιστημόνων είναι απλά να περιγράφουν φαινόμενα στη φύση, π.χ. να μπορούν να πουν τι είναι οι σεισμοί. Δε νομίζω ότι η δουλειά τους είναι τόσο περίπλοκη όσο λες.*
Γιώργος: *Η δουλειά τους έχει σκοπό να επεξηγεί όσο γίνεται καλύτερα τα διάφορα φυσικά φαινόμενα*

Α. Συμφωνώ απολύτως με το Γιώργο
Β. Αν και συμφωνώ περισσότερο με το Γιώργο νομίζω ότι και ο Αντώνης έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με τον Αντώνη νομίζω ότι και ο Γιώργος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τον Αντώνη

9. Η Χαρά και η Εύη διαφωνούν για τη γνώση στην επιστήμη
Χαρά: *Η επιστήμη μοιάζει κάπως με τη μόδα: κάτι που είναι στη μόδα τη μια χρόνια, μπορεί να μην είναι στη μόδα την επόμενη χρονιά. Οι επιστήμονες αλλάζουν τις θεωρίες τους κάποτε προς κάτι νέο κάποτε προς κάτι που ήταν ήδη γνωστό από πριν.*
Εύη: *Διαφωνώ. Πιστεύω ότι όταν γίνουν κάποια πειράματα και με βάση τα αποτελέσματά τους δημιουργηθούν θεωρίες τότε οι θεωρίες ισχύουν και το θέμα έχει κλείσει. Δεν υπάρχει λόγος για άλλη συζήτηση. Δε νομίζω ότι μπορεί η γνώση στην επιστήμη να αλλάζει.*
Χαρά: Η γνώση μπορεί να αλλάξει μέσα από την έρευνα που κάνουν οι επιστήμονες.

Α. Συμφωνώ απολύτως με τη Χαρά
Β. Αν και συμφωνώ περισσότερο με τη Χαρά νομίζω ότι και η Εύη έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με την Εύη νομίζω ότι και η Χαρά έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με την Εύη

10. Η Μάρθα και η Σοφία διαφωνούν όπως φαίνεται πιο κάτω:
Μάρθα: *Παρακολουθούσα τις ειδήσεις πριν λίγες μέρες και μου έκανε μεγάλη εντύπωση που δύο επιστήμονες διαφωνούσαν για ένα εμβόλιο κατά της γρίπης! Δεν μπορούσαν να συμφωνήσουν για το αν το εμβόλιο κάνει καλό ή όχι!*
Σοφία: *Σε εμένα δε φαίνεται και πολύ παράξενο αυτό που λες. Συμβαίνει πολύ συχνά οι επιστήμονες να διαφωνούν για ένα θέμα. Αυτό συμβαίνει γιατί οι ιδέες τους και οι θεωρίες που υποστηρίζουν είναι διαφορετικές.*
Μάρθα: *Ναι, αλλά θα πρέπει να μπορούν να συμφωνήσουν αν κάτι είναι σωστό ή όχι, όσο διαφορετικές ιδέες κι αν έχουν.*

Α. Συμφωνώ απολύτως με τη Μάρθα
Β. Αν και συμφωνώ περισσότερο με τη Μάρθα νομίζω ότι και η Σοφία έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Σοφία νομίζω ότι και η Μάρθα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Σοφία

11. Ο Στέφανος και ο Μάριος κάνουν μια συζήτηση για τις γνώσεις στην επιστήμη
Στέφανος: *Κάθε καινούργια γνώση στην επιστήμη συνδέεται με τα όσα γνωρίζουν οι επιστήμονες μέχρι εκείνη τη στιγμή. Άρα δεν πρέπει συνέχεια απλά να προσθέτουν σε αυτά που ξέρουν. Πολλές φορές όταν ανακαλυφθεί κάτι καινούργιο οι επιστήμονες μπορεί να χρειάζεται να αλλάξουν τα όσα ήξεραν μέχρι εκείνη τη στιγμή*
Μάριος: *Διαφωνώ με αυτό που λες. Δεν πιστεύω ότι οι γνώσεις στην επιστήμη συνδέονται τόσο πολύ μεταξύ τους.*
Κάθε διαφορετική ανακάλυψη ή κάθε διαφορετικό θέμα προστίθεται σε όλα τα υπόλοιπα που γνωρίζουν οι επιστήμονες μέχρι εκείνη τη στιγμή. Κάθε επιστήμονας θα πρέπει να είναι μια κινητή βιβλιοθήκη!
Στέφανος*: Α μπα! Αδύνατο ακούγεται αυτό που λες!*

Α. Συμφωνώ απολύτως με το Στέφανο
Β. Αν και συμφωνώ περισσότερο με το Στέφανο νομίζω ότι και ο Μάριος έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τους δύο
Δ. Αν και συμφωνώ περισσότερο με το Μάριο νομίζω ότι και ο Στέφανος έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με το Μάριο

12. Η Αλεξάνδρα και η Δανάη διαφωνούν όπως φαίνεται παρακάτω:
Αλεξάνδρα: *Τα πειράματα βοηθούν τους επιστήμονες να βρουν μια θεωρία.*
Δανάη*: Εγώ αντίθετα νομίζω ότι τα πειράματα βοηθούν τους επιστήμονες να διαλέξουν την καλύτερη ανάμεσα σε διάφορες θεωρίες.*
Αλεξάνδρα: *Διαφωνώ. Ένα πείραμα πρέπει να σχετίζεται μόνο μια θεωρία.*

Α. Συμφωνώ απολύτως με την Αλεξάνδρα
Β. Αν και συμφωνώ περισσότερο με την Αλεξάνδρα νομίζω ότι και η Δανάη έχει κάποιο δίκαιο
Γ. Συμφωνώ το ίδιο και με τις δύο
Δ. Αν και συμφωνώ περισσότερο με τη Δανάη νομίζω ότι και η Αλεξάνδρα έχει κάποιο δίκαιο
Ε. Συμφωνώ απολύτως με τη Δανάη

Appendix C

ΠΡΟΗΓΟΥΜΕΝΕΣ ΓΝΩΣΕΙΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ (Α)

Όνομα: ____Τάξη: ______ Ημ..:

1. **Στις πιο κάτω δηλώσεις κύκλωσε το Σ αν η δήλωση είναι Σωστή ή το Λ αν είναι Λάθος**

   Α. Η τριβή δυσκολεύει την κίνηση Σ Λ

   Β. Η ρίζα ενός φυτού στρέφεται προς τα πάνω και ο βλαστός προς τα κάτω Σ Λ

   Γ. Τα δόντια μας βοηθούν στη χώνεψη των τροφών Σ Λ

   Δ. Ένα σώμα όταν θερμανθεί διαστέλλεται και όταν ψυχθεί συστέλλεται Σ Λ

   Ε. Σε ένα απλό ηλεκτρικό κύκλωμα το λαμπάκι ανάβει όταν το κύκλωμα είναι ανοικτό Σ Λ

   ΣΤ. Τα αέρια διαστέλλονται περισσότερο από τα υγρά και τα υγρά περισσότερο από τα στερεά όταν αυτά θερμανθούν το ίδιο. Σ Λ

   Ζ. Όταν φέρουμε κοντά δύο καλαμάκια που είναι φορτισμένα αρνητικά, τα καλαμάκια απωθούνται Σ Λ

   Η. Η ζάχαρη διαλύεται πιο γρήγορα στο κρύο νερό Σ Λ

2. **Στις πιο κάτω δηλώσεις διάλεξε τη σωστή απάντηση**

   Α. Ο Αντρέας προσπαθεί να μετακινήσει ένα βαρύ κιβώτιο. Σε ποια επιφάνεια από τις πιο κάτω θα χρειαστεί τη λιγότερη δύναμη;

   α. Πάτωμα από κεραμικά
   β. Χώμα
   γ. Τσιμεντένιο δάπεδο
   δ. Πάτωμα όπου έχει χυθεί λάδι

   Β. Τα φυτά διαπνέουν, δηλαδή αποβάλλουν νερό από τα φύλλα τους. Ποιος από τους πιο κάτω παράγοντες επηρεάζει τη διαπνοή τους;

   α. Ύψος φυτών
   β. Σχήμα των φύλλων
   γ. Μέγεθος επιφάνειας των φύλλων
   δ. Είδος του χώματος

Γ. Ποια από τις πιο κάτω συνήθειες βοηθά στην προστασία των δοντιών μας;

α. Καθαρίζουμε τα δόντια μας μόνο το πρωί μόλις ξυπνήσουμε
β. Αποφεύγουμε τα πολλά γλυκά
γ. Επισκεπτόμαστε τον οδοντίατρο μόνο όταν έχουμε πονόδοντο
δ. Σπάζουμε με τα δόντια μας ξηρούς καρπούς

Δ. Τα ηλεκτρικά φορτία σε ένα νέφος δημιουργούνται από:
α. Τους κεραυνούς και τις αστραπές
β. Την τριβή των σύννεφων με τον αέρα
γ. Τις βροντές
δ. Την τριβή των κεραυνών με τα σύννεφα

Ε. Προστατεύει τα κτίρια από τον κεραυνό:
α. Το αλεξικέραυνο
β. Το ηλεκτροσκόπιο
γ. Το βροχόμετρο
δ. Το αλεξίσφαιρο

3. Συμπλήρωσε τα κενά

α. Χρησιμοποιώντας λάδι σε μια επιφάνεια πετυχαίνουμε να μειώσουμε την

τριβή, ώστε να .... η κίνηση.

β. Αυξάνοντας το βάρος ενός κιβωτίου πετυχαίνουμε να αυξήσουμε την τριβή,

ώστε να .... η κίνησή του.

4. Σε ποιο χαρακτηριστικό διαφέρουν τα ζώα που είναι σπονδυλωτά από τα ζώα που δεν είναι σπονδυλωτά;

....

5. Στα φυτά γίνεται μια λειτουργία που ονομάζεται φωτοσύνθεση. Να γράψεις ένα λόγο για τον οποίο η φωτοσύνθεση είναι πολύ σημαντική λειτουργία στα φυτά.

....

....

6. **Α. Να γράψεις ένα τρόπο με τον οποίο τα φρύδια βοηθούν στην προστασία του ματιού**

   ....

   Β. Να γράψεις ένα τρόπο με τον οποίο τα βλέφαρα βοηθούν στην προστασία του ματιού

   ....

7. **Τα ζώα προσαρμόζονται στο περιβάλλον τους για να επιβιώσουν. Ποιο χαρακτηριστικό της πολικής αρκούδας τη βοηθά να προσαρμόζεται;**

   ....

   ....

8. **Αν αναμίξω νερό και αλάτι και ανακατέψω αρκετή ώρα θα φτιάξω ένα διάλυμα. Αν αναμίξω νερό και λάδι και ανακατέψω αρκετή ώρα θα έχω και πάλι ένα διάλυμα; Δικαιολόγησε την απάντησή σου.**

   ....

   ....

9. **Γράψε τρεις τρόπους εξοικονόμησης νερού στο σπίτι.**

   α...

   β..

   γ...

10. Αντιστοίχισε το κάθε ζώο με την κατηγορία στην οποία ανήκει. Να γράψεις δίπλα από κάθε ζώο το γράμμα που αντιστοιχεί.

1. Άλογο	α. χειρόπτερα
	β. αρθρόποδα
2. Ελέφαντας	γ. οπλωτά
	δ. προβοσκιδωτά
3. Φάλαινα	ε. πρωτεύοντα
	ζ. κητώδη
4. Πίθηκος	η. τρωκτικά

11. Να γράψεις δύο οφέλη της ανακύκλωσης

α...

β...

12. Να περιγράψεις ένα πείραμα για να δείξεις το ρόλο που παίζει το μέγεθος ενός τροχού στην κίνηση ενός κιβωτίου. Να γράψεις τα υλικά που θα χρησιμοποιήσεις και τη διαδικασία του πειράματος, δηλαδή τι ακριβώς σκοπεύεις να κάνεις με αυτά τα υλικά.

ΥΛΙΚΑ:

....

....

ΔΙΑΔΙΚΑΣΙΑ:

....

....

....

....

....

13. Υπογράμμισε όσα από τα πιο κάτω έχουν σχέση με την καλή χώνευση

Α. Κατά τη διάρκεια του φαγητού δεν πίνουμε πολύ νερό
Β. Αποφεύγουμε τις βαριές εργασίες μετά το γεύμα
Γ. Τρώμε, μασάμε και καταπίνουμε γρήγορα
Δ. Κρατούμε μακριά από το φαγητό τις λύπες, τους θυμούς και τις στενοχώριες

14. Υπογράμμισε όσα από τα πιο κάτω ισχύουν για τα μάτια μας

Α. Τα βλέφαρα ανοιγοκλείνουν για να υγραίνεται το μάτι
Β. Με το φακό βλέπουμε πιο καθαρά τόσο τα κοντινά όσο και τα μακρινά αντικείμενα
Γ. Τα δύο μάτια μας βοηθούν να υπολογίζουμε καλύτερα τις αποστάσεις μεταξύ των διαφόρων σωμάτων
Δ. Στο λιγοστό φως η κόρη του ματιού στενεύει

15. Σε τι μετατρέπεται ο ηλεκτρισμός σε μια τηλεόραση; Υπογράμμισε αυτά που ισχύουν.

Α. Θερμότητα
Β. Φως
Γ. Ήχος
Δ. Κίνηση

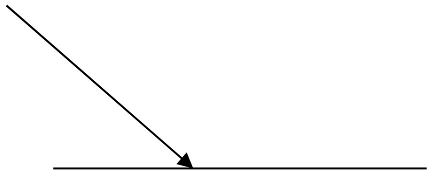
16. Σχεδίασε την κόρη του ματιού μας στο φως και στο σκοτάδι

ΦΩΣ	**ΣΚΟΤΑΔΙ**

17. Στη λέξη ΑΛΛΑ πού πρέπει να τοποθετήσουμε τον καθρέφτη για να διαβάσουμε τη λέξη μισή από το χαρτί και μισή στον καθρέφτη; Σχεδίασε μια γραμμή εκεί που πρέπει να τοποθετηθεί ο καθρέφτης

Α Λ Λ Α

18. **Το πιο κάτω σχεδιάγραμμα παρουσιάζει μια ακτίνα φωτός που προσπίπτει σε καθρέφτη. Σχεδίασε την ανάκλαση της ακτίνας αυτής**

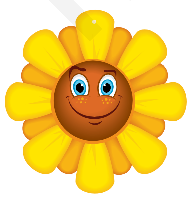


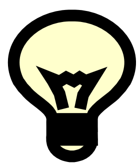
19. **Σχεδίασε ένα ανοικτό ηλεκτρικό κύκλωμα.**

20. **Οι αγωγοί επιτρέπουν στο ηλεκτρικό ρεύμα να περάσει από μέσα τους και οι μονωτές αποτρέπουν το ηλεκτρικό ρεύμα να περάσει από μέσα τους. Στα πιο κάτω υλικά σημείωσε με Α τους αγωγούς και Μ τους μονωτές**

Χαλκός	......	Νερό	......
Ξύλο	......	Χαρτί	......
Ύφασμα	......	Μολύβι	......
Σίδηρος	......	Πλαστικό	......
Γυαλί	......	Αλουμίνιο	......

21. **Κύκλωσε όσα από τα πιο κάτω σχήματα θα φαίνονται τα ίδια όταν τα κοιτάξουμε μέσα από ένα καθρέφτη που τοποθετείται στο πλάι τους.**





Γ **Ζ**

22. Α. Να σχεδιάσεις ένα καλώδιο στο ηλεκτρικό κύκλωμα ώστε να συμβεί βραχυκύκλωμα

Β. Εξήγησε γιατί συμβαίνει βραχυκύκλωμα

....

....

....

APPENDIX D

ΠΡΟΣΩΠΙΚΟ ΕΝΔΙΑΦΕΡΟΝ (Α)

Όνομα: ______________________________________Τάξη: ______ Ημ..: ______

1. Κυκλώνω το παιδί με το οποίο συμφωνώ περισσότερο

Βαριέμαι πάρα πολύ στην επιστήμη. Προτιμώ να κάνω οποιοδήποτε άλλο μάθημα!

Α

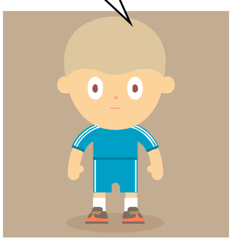
Δε μου αρέσει και πολύ το μάθημα της Επιστήμης

Β

Δεν ξεχωρίζω ιδιαίτερα το μάθημα της Επιστήμης από τα άλλα μαθήματα.

Γ

Προτιμώ το μάθημα της επιστήμης από άλλα μαθήματα



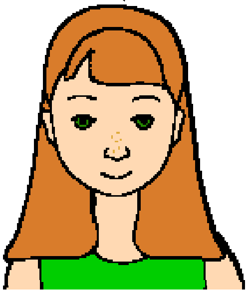
Δ

Προτιμώ το μάθημα της Επιστήμης περισσότερο από οποιοδήποτε άλλο μάθημα! Είναι το αγαπημένο μου μάθημα!

Ε

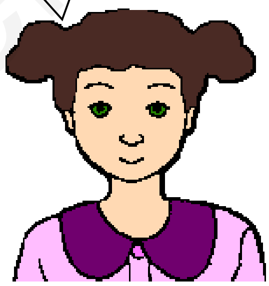
2. Κυκλώνω το παιδί με το οποίο συμφωνώ περισσότερο

Όταν παρακολουθώ νέα και αρχίσει μία είδηση σχετική με επιστήμη αλλάζω αμέσως κανάλι. Τις βαριέμαι πολύ!



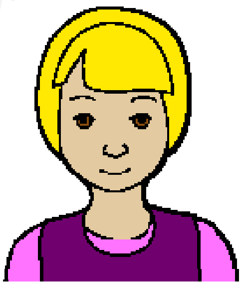
Α

Όταν παρακολουθώ νέα και αρχίσει μία είδηση σχετική με την επιστήμη παρακαλώ να τελειώσει όσον το δυνατό γρηγορότερα



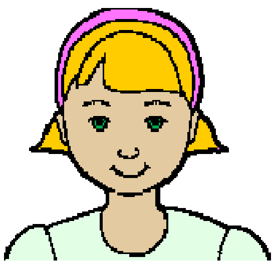
Β

Για μένα οι ειδήσεις σχετικές με νέα της επιστήμης δεν έχουν καμία διαφορά από άλλες ειδήσεις



Με ενδιαφέρει να βλέπω στην τηλεόραση ειδήσεις για την επιστήμη

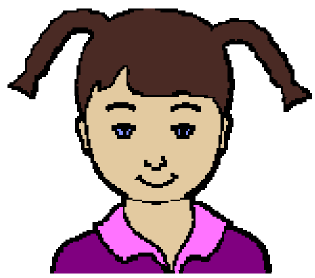
Γ



Δ

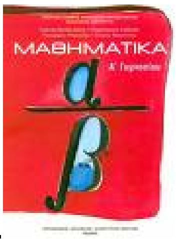
Όταν παρακολουθώ ειδήσεις και ακούσω κάποιο νέο σχετικό με επιστήμη το βλέπω με πολύ μεγάλο ενδιαφέρον

Ε

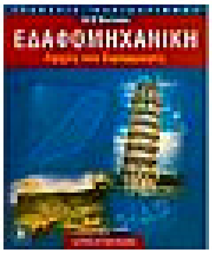


3. Αν είχα χρόνο ποιο βιβλίο θα ήθελα να διαβάσω; Βάζω δίπλα από κάθε βιβλίο τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από το βιβλίο που προτιμώ περισσότερο βάζω τον αριθμό 1 και στο βιβλίο που προτιμώ λιγότερο τον αριθμό 5.

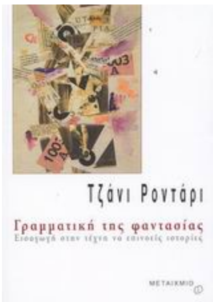
Α. ....



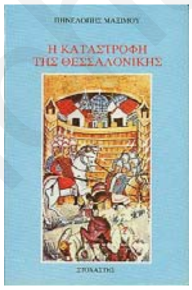
Β. ......



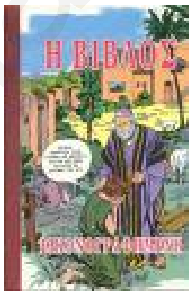
Γ. ......



Δ ....



Ε ......



4. Ποια ταινία θα παρακολουθούσα στον ελεύθερο μου χρόνο; Βάζω δίπλα από κάθε ταινία τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από την ταινία που προτιμώ περισσότερο βάζω τον αριθμό 1 και στην ταινία που προτιμώ λιγότερο τον αριθμό 5.

Α. Ντοκυμαντέρ για την τριβή ......
Β. Η ζωή του Χριστού ......
Γ. Στα χρόνια της τουρκοκρατίας ......
Δ. Φοίνικες και Μαθηματικά ......
Ε. Η ελληνική γλώσσα σήμερα ......

5. Ποιο μουσείο θα ήθελα να επισκεφθώ αν επισκεπτόμουν την Αμερική; Βάζω δίπλα από κάθε μουσείο τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από το μουσείο που προτιμώ περισσότερο βάζω τον αριθμό 1 και στο μουσείο που προτιμώ λιγότερο τον αριθμό 5.

Α. Εθνικό Μουσείο Αεροναυτικής και Διαστήματος ......
Β. Αμερικανικό Μουσείο Ιστορίας ......
Γ. Εθνικό Μουσείο Μαθηματικών ......
Δ. Αμερικανικό Μουσείο Αγγλικής Γλώσσας ......
Ε. Αμερική και άλλες Θρησκείες ......

6. Η δασκάλά σας σάς έχει δώσει οδηγίες για ένα project και σας έδωσε τις πιο κάτω επιλογές. Ποιο από τα πιο κάτω θα διαλέξεις; Βάζω δίπλα από κάθε οδηγία τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από την οδηγία που προτιμώ περισσότερο βάζω τον αριθμό 1 και στην οδηγία που προτιμώ λιγότερο τον αριθμό 5.

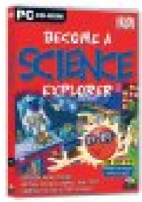
Α. Μαθαίνω περισσότερα για τα χρόνια της τουρκοκρατίας και γράφω για την καθημερινή ζωή των Ελλήνων εκείνη την εποχή. ....
Β. Μελετώ για τον ηλεκτρισμό, συγκεντρώνω πληροφορίες και γράφω για το πώς ξεκίνησε ο ηλεκτρισμός (ο εφευρέτης του, τα πρώτα πειράματα, κλπ) ....
Γ. Συγκεντρώνω πληροφορίες και γράφω για παραδείγματα από τη ζωή του Χριστού από τα οποία φαίνεται η μεγάλη του αγάπη για τα παιδιά. ....
Δ. Μαθαίνω περισσότερα και γράφω για τη συνεισφορά των Αζτέκων στα μαθηματικά ....
Ε. Ανακαλύπτω λέξεις στα ελληνικά που έχουμε δανειστεί από άλλες γλώσσες ....

7. Έχεις λάβει μέρος σε ένα διαγωνισμό γενικών γνώσεων και το βραβείο είναι να γνωρίσεις από κοντά ένα επιστήμονα με ειδικότητα που θα προτιμούσες εσύ. Ποια ειδικότητα θα διάλεγες αν κέρδιζες το διαγωνισμό; Βάζω δίπλα από κάθε επιστήμονα τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από τον επιστήμονα που προτιμώ περισσότερο βάζω τον αριθμό 1 και στον επιστήμονα που προτιμώ λιγότερο τον αριθμό 5.

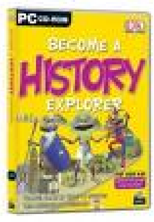
Α. Ιστορικό ....
Β. Μαθηματικό ....
Γ. Θεολόγο ....
Δ. Γλωσσολόγο ....
Ε. Φυσικό ....

8. Ποιο από τους πιο κάτω ψηφιακούς δίσκους θα επέλεγες να είναι το επόμενο δώρο γενεθλίων σου; Βάζω δίπλα από κάθε δίσκο τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από το δίσκο που προτιμώ περισσότερο βάζω τον αριθμό 1 και στο δίσκο που προτιμώ λιγότερο τον αριθμό 5.

Α. Γρήγορα Μαθηματικά......

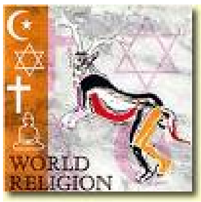


Β. Γίνε ένας εξερευνητής της επιστήμης.....



Γ. Γίνε ένας εξερευνητής της ιστορίας.....

(συνέχεια στην επόμενη σελίδα)



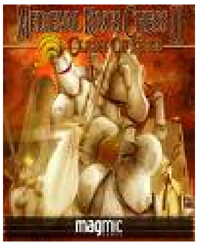
Δ. Οι θρησκείες του κόσμου .....

Ε. Εργαστήριο Γλώσσας ......

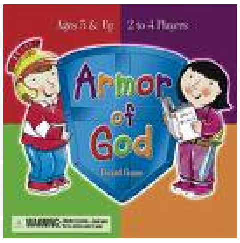
9. Ποιο από τα πιο κάτω επιτραπέζια θα ήθελες να έπαιζες με τους φίλους σου; Βάζω δίπλα από κάθε παιχνίδι τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από το παιχνίδι που προτιμώ περισσότερο βάζω τον αριθμό 1 και στο παιχνίδι που προτιμώ λιγότερο τον αριθμό 5.

Α. Το παιχνίδι των τυφώνων .....

Β. Μαθηματικό γυμναστήριο ....



Γ. Βασιλιάδες του Μεσαίωνα ......

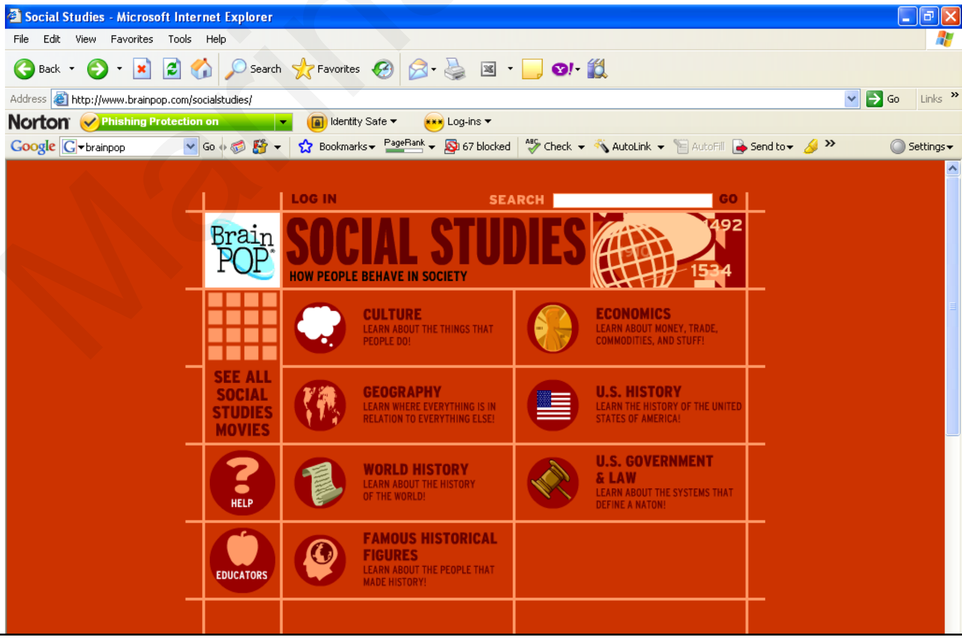


Δ. Η προστασία του Θεού ......

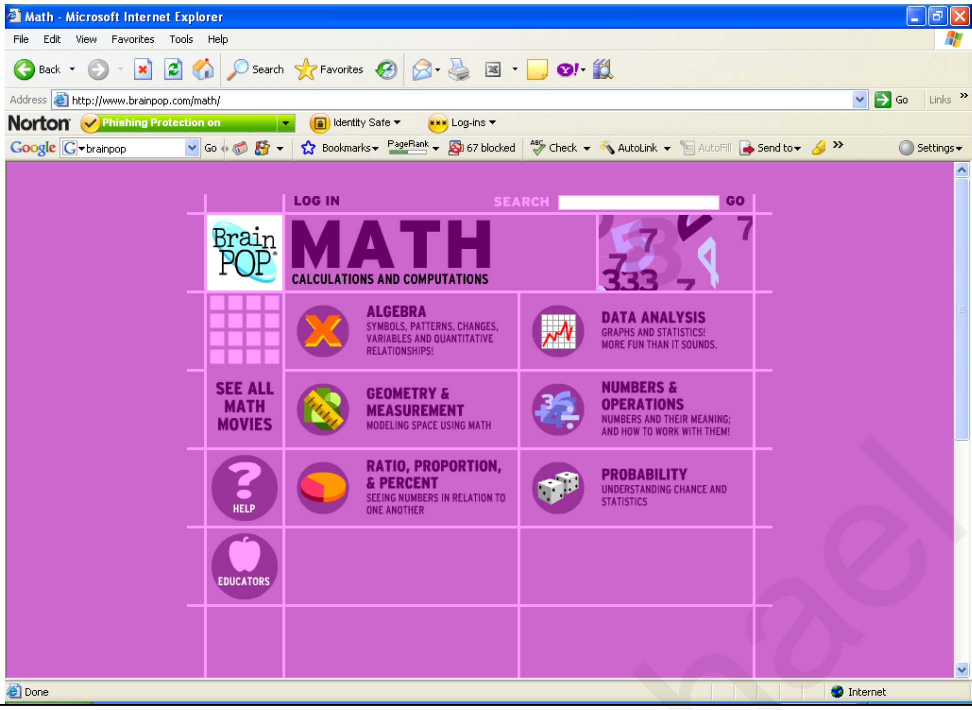
Ε. Φτιάχνω τις δικές μου ιστορίες ....

10. Ποια από τις πιο κάτω ιστοσελίδες σου φαίνεται πιο ενδιαφέρουσα; Βάζω δίπλα από κάθε ιστοσελίδα τους αριθμούς 1-5 σύμφωνα με την προτίμησή μου. Δίπλα από την ιστοσελίδα που προτιμώ περισσότερο βάζω τον αριθμό 1 και στην ιστοσελίδα που προτιμώ λιγότερο τον αριθμό 5.

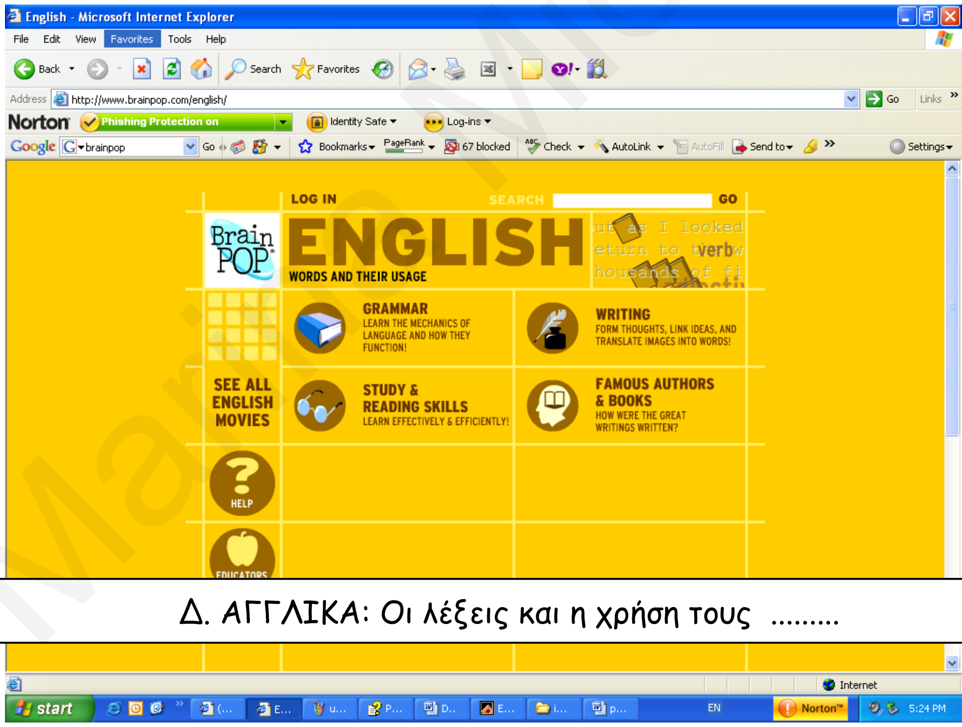
Α. ΕΠΙΣΤΗΜΗ: ΠΩΣ ΛΕΙΤΟΥΡΓΕΙ Ο ΚΟΣΜΟΣ ......



Β. Κοινωνικές Επιστήμες (Ιστορία, Γεωγραφία, κλπ): Πώς συμπεριφέρονται οι άνθρωποι στην κοινωνία ....



Γ. Μαθηματικά: Υπολογισμοί και Πράξεις ....



Δ. ΑΓΓΛΙΚΑ: Οι λέξεις και η χρήση τους ....

Ε. ΘΡΗΣΚΕΙΕΣ ΑΠΟ ΟΛΟ ΤΟΝ ΚΟΣΜΟ: Βουδισμός, Χριστιανισμός, Ινδουισμός, Ισλάμ, Ιουδαϊσμός, κ.α.

Appendix E

Baseline Text

<u>Η ΓΝΩΣΗ ΣΤΗΝ ΕΠΙΣΤΗΜΗ ΑΛΛΑΖΕΙ Ή ΜΕΝΕΙ ΣΤΑΘΕΡΗ;</u>

Όταν οι επιστήμονες θέλουν να περιγράψουν και να εξηγήσουν ένα φαινόμενο στη φύση τότε κάνουν διάφορες έρευνες και πειράματα. Μέσα από αυτά μπορεί να καταλήξουν σε κάποια αποτελέσματα και συμπεράσματα. Αν επαναλάβουν τα ίδια πειράματα και συνεχίζουν να βρίσκουν τα ίδια αποτελέσματα τότε μπορεί να καταλήξουν σε μια θεωρία. Μπορεί πάλι ίσως να επιβεβαιώσουν μια θεωρία που γνώριζαν από πριν.

Έτσι λοιπόν οι θεωρίες στην επιστήμη δημιουργούνται για να περιγράψουν και να εξηγήσουν τα διάφορα φαινόμενα που συμβαίνουν γύρω μας. Όμως, οι διάφορες θεωρίες που δημιουργούνται μπορεί να αλλάξουν. Οι επιστήμονες ερευνούν συνεχώς τα διάφορα φαινόμενα της φύσης. Μέσα από πολλές έρευνες και πειράματα ανακαλύπτουν νέα στοιχεία. Αυτά τα νέα στοιχεία πολλές φορές συμπληρώνουν όσα γνωρίζαμε μέχρι εκείνη τη στιγμή. Αυτό έχει ως αποτέλεσμα οι θεωρίες που έχουμε να περιγράφουν καλύτερα κάποιο φαινόμενο.

Άλλοτε πάλι, τα νέα στοιχεία δείχνουν ότι τα όσα γνωρίζαμε μέχρι εκείνη τη στιγμή ίσως να μην είναι και τόσο σωστά. Με βάση αυτά τα νέα στοιχεία μπορεί να γίνουν πολλές έρευνες. Εάν αυτές οι έρευνες δείχνουν κάθε φορά το ίδιο συμπέρασμα τότε μιλάμε για μια νέα θεωρία. Η νέα αυτή θεωρία μπορεί να εξηγεί καλύτερα το συγκεκριμένο φαινόμενο. Εάν συμβαίνει κάτι τέτοιο η νέα θεωρία θα αλλάξει τα όσα γνωρίζαμε μέχρι εκείνη τη στιγμή.

DOES KNOWLEDGE IN SCIENCE CHANGE OR REMAINS STABLE?

When scientists want to describe and explain a phenomenon in nature they do research and conduct different experiments. Through their research and experiments they derive results and conclusions. If they repeat the same experiments and continue to find the same results, then they may end up with a theory. Alternatively, they could confirm an existing theory.

Thus, the different theories in science are developed in order to describe and explain the various phenomena that occur in our world. However, the different theories that are developed could change. Scientists continuously investigate various phenomena in nature. Through numerous research projects and experiments they discover new evidence. This new evidence may extend our knowledge up to that point. As a result, existing theories describe phenomena more adequately.

New evidence may indicate however, that our existing knowledge may not be as valid as we thought it was. This new evidence may lead to new research efforts. If these research studies show repeatedly the same conclusions, then we may have a new theory. If this happens, then the new theory will change our existing knowledge.

ΣΧΕΤΙΖΟΝΤΑΙ ΟΙ ΓΝΩΣΕΙΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ Ή ΕΙΝΑΙ ΑΣΧΕΤΕΣ ΜΕΤΑΞΥ ΤΟΥΣ;

Η γνώση στην επιστήμη δημιουργείται μέσα από την εργασία που κάνουν οι επιστήμονες. Αρκετά συχνά, μέσα από τις διάφορες έρευνες και τα πειράματα που κάνουν, καταλήγουν σε νέα γνώση.

Οι γνώσεις στην επιστήμη δεν είναι ξεκομμένες η μία από την άλλη, αλλά συνδέονται. Οι επιστήμονες για να κάνουν ένα πείραμα ή μια έρευνα δεν ξεκινούν από το μηδέν. Πριν κάνουν το πείραμά τους φροντίζουν να ενημερώνονται καλά για τη γνώση που υπάρχει για το συγκεκριμένο θέμα μέχρι εκείνη τη στιγμή. Συμβαίνει πολύ συχνά άλλοι επιστήμονες να έχουν ερευνήσει κάτι παρόμοιο. Όταν θα τελειώσει το πείραμα οι επιστήμονες πιθανόν να μάθουν κάτι καινούργιο. Έτσι, αυτό το καινούργιο θα έχει κάποια σχέση, μικρή ή μεγάλη με τα αποτελέσματα άλλων πειραμάτων για το ίδιο θέμα. Μπορεί πάλι να έχει κάποια σχέση με παρόμοιο θέμα ή ακόμα και με κάποιο άλλο θέμα που μπορεί να φαίνεται άσχετο.

Έτσι λοιπόν οι γνώσεις στην επιστήμη συσχετίζονται μεταξύ τους με πάρα πολλούς τρόπους. Πολλές φορές αν δεν καταλάβουμε τι σχέση υπάρχει μεταξύ των διαφορετικών κομματιών γνώσης μπορεί να μην μπορούμε να κατανοήσουμε ένα φυσικό φαινόμενο. Επομένως, οι επιστήμονες για να βγάλουν τα σωστά συμπεράσματα από τα πειράματά τους θα πρέπει να συνδέσουν τις γνώσεις μεταξύ τους. Χρειάζεται δηλαδή να εξηγήσουν ποια σχέση υπάρχει μεταξύ του καινούργιου (που έχουν μάθει από το δικό τους πείραμα) και της γνώσης που υπήρχε ήδη μέχρι εκείνη τη στιγμή. Η σύνδεση των γνώσεων είναι αυτή που θα τους βοηθήσει να κατανοήσουν και να εξηγήσουν καλύτερα τα διάφορα φαινόμενα που μελετούν.

Από όλα αυτά καταλαβαίνουμε ότι στην επιστήμη τίποτα δεν είναι ξεκομμένο. Κάθε τι καινούργιο συνδέεται, έχει σχέση, δηλαδή, με τα όσα γνωρίζαμε για το συγκεκριμένο θέμα ή και για άλλα θέματα μέχρι εκείνη τη στιγμή.

ARE DIFFERENT PARTS OF KNOWLEDGE IN SCIENCE INTERRELATED OR UNRELATED TO EACH OTHER?

Knowledge in science derives from scientists' work. Through research and experiments scientists often end up with new knowledge.

Parts of knowledge in science are interrelated. In order to conduct an experiment or complete a research project, scientists do not start from zero. Before they conduct their experiments they make sure to get informed about existing knowledge on the particular topic. Other scientists may have researched a similar topic. On the completion of the experiment, scientists may find out something new. Therefore, this new piece of knowledge may be related to a large or a small extent to the results of other experiments on the same topic. It could even be related to a similar topic or to another topic that seems totally different.

Different parts of knowledge in science are therefore interrelated via many different ways. We may often have a hard time trying to understand a natural phenomenon, without understanding first the relationship between the different parts of knowledge. As a result, scientists need to establish the connections between the different parts of knowledge in order to derive the right conclusions from their experiments. In other words, they need to explain how the new piece of knowledge (derived from their own experiments) relates to existing knowledge. Interrelatedness of knowledge will help them better understand and explain the different phenomena they examine.

As a result, everything in science is interrelated. Every new piece of knowledge connects or relates to everything that we knew for the particular topic or other topics until that point in time.

ΠΟΙΟΣ ΕΙΝΑΙ Ο ΡΟΛΟΣ ΤΩΝ ΙΔΕΩΝ ΤΟΥ ΕΠΙΣΤΗΜΟΝΑ ΣΤΗΝ ΕΡΕΥΝΑ;

Οι επιστήμονες ενημερώνονται για τις γνώσεις που ήδη υπάρχουν για ένα φαινόμενο πριν σχεδιάσουν και κάνουν ένα δικό τους πείραμα ή μια παρατήρηση. Όμως για να σχεδιάσουν σωστά το δικό τους πείραμα, θα πρέπει να σκεφτούν τι σημαίνουν οι γνώσεις που ήδη υπάρχουν και αν εξηγούν καλά το φαινόμενο ή όχι. Θα πρέπει ακόμα να σκεφτούν με ποιες άλλες γνώσεις συνδέονται οι γνώσεις που υπάρχουν για το συγκεκριμένο φαινόμενο. Θα πρέπει δηλαδή να καταλαβαίνουν καλά ποια είναι η γνώση που υπάρχει για το θέμα που θέλουν να μελετήσουν.

Ένας καλός επιστήμονας όμως, δε φτάνει να ξέρει καλά τις γνώσεις που έχουν ανακαλύψει οι υπόλοιποι επιστήμονες. Θα πρέπει να έχει νέες ιδέες και να σχεδιάζει τα δικά του πειράματα ή έρευνες για να ελέγξει αν οι ιδέες του ισχύουν. Έτσι λοιπόν, κάθε έρευνα στην επιστήμη στηρίζεται σε προηγούμενες γνώσεις. Η έρευνα στηρίζεται όμως και στον τρόπο με το οποίο σκέφτονται οι επιστήμονες για αυτές τις γνώσεις. Δηλαδή, στις ιδέες που έχουν οι επιστήμονες!

Τα αποτελέσματα των πειραμάτων δεν είναι από μόνα τους γνώση. Όταν οι επιστήμονες ολοκληρώσουν ένα πείραμα ή μια παρατήρηση θα πρέπει να σκεφτούν τι σημαίνουν τα αποτελέσματά τους. Με αυτό τον τρόπο θα βγάλουν συμπεράσματα από τα αποτελέσματά τους και θα εξηγήσουν με ποιο τρόπο οι ιδέες τους, που οδήγησαν στο πείραμα, εξηγούν το φαινόμενο που μελέτησαν. Για να βγάλουν τα σωστά συμπεράσματα χρειάζεται ακόμα να σκεφτούν και με ποιες άλλες προηγούμενες γνώσεις συνδέονται αυτά που ανακάλυψαν. Η επιστημονική γνώση, λοιπόν, είναι η ερμηνεία των αποτελεσμάτων. Με άλλα λόγια ο τρόπος που οι επιστήμονες σκέφτονται και εξηγούν τα αποτελέσματα του πειράματος και βγάζουν τα συμπεράσματά τους.

Επίσης, οι επιστήμονες δεν ανακαλύπτουν απλώς τι υπάρχει και τι συμβαίνει στη φύση. Είναι σημαντικό να γνωρίζουμε ότι κάθε επιστήμονας εξηγεί τα αποτελέσματα πειραμάτων και ερευνών και βγάζει συμπεράσματα ανάλογα με τις δικές του ιδέες και θεωρίες.

WHAT IS THE ROLE OF SCIENTISTS' IDEAS IN SCIENCE?

Before scientists conduct an experiment they get informed about existing knowledge. In order to design their own experiment in the right way, they need to think well what existing knowledge tells us and whether it explains the phenomenon well. They also need to think to what other knowledge about the particular topic existing knowledge connects to. In other words, scientists need to understand well existing knowledge about the topic they would like to study.

It is not enough for good scientists however, to merely know the knowledge discovered by other scientists. Good scientists need to think of new ideas and design their own experiments or research in order to examine the validity of their ideas. Research in science builds therefore from previous knowledge. It is noteworthy however, that research also depends a lot on the way scientists think about knowledge. In other words, research depends on scientists' ideas!

A research result cannot be considered knowledge in and of itself. When scientists complete an experiment or a scientific observation they need to think what is the meaning of their results. This way they will derive conclusions from their results and they will explain how their ideas that originated the experiment in the first place explain the particular phenomenon they studied. Scientific knowledge is therefore the interpretation of the results. In other words, it is the way scientists think and explain experimental results and derive conclusions.

Moreover, scientists do not just discover natural phenomena and how they occur. It is important to realize that every scientist explains the results of research and experiments and derives conclusions on the basis of his/her ideas and theories.

ΠΟΙΟΣ ΕΙΝΑΙ Ο ΡΟΛΟΣ ΤΟΥ ΠΕΙΡΑΜΑΤΟΣ ΚΑΙ ΤΗΣ ΕΡΕΥΝΑΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ;

Οι επιστήμονες δεν μπορούν απλά να σκεφτούν μια έξυπνη ιδέα ή μια καινούργια θεωρία και να την παρουσιάσουν ως νέα γνώση στην επιστήμη. Όταν σκεφτούν μια νέα ιδέα ή θεωρία θα πρέπει πρώτα να ψάξουν και να βρουν τι γνωρίζουν οι υπόλοιποι επιστήμονες για το συγκεκριμένο θέμα. Θα πρέπει να βρουν τι πειράματα και τι έρευνες έχουν γίνει για αυτό το θέμα. Στη συνέχεια θα σχεδιάσουν τα δικά τους πειράματα με σκοπό να βρουν αν η αρχική τους ιδέα είναι σωστή. Θα ελέγξουν δηλαδή αν η ιδέα τους μπορεί να εξηγήσει το φαινόμενο που μελετούν.

Μια παρατήρηση ή μόνο ένα πείραμα που να δείχνει μια ιδέα σωστή δεν είναι αρκετό. Έτσι λοιπόν οι επιστήμονες θα κάνουν πολλές παρατηρήσεις και πειράματα και θα εξετάζουν κάθε φορά αν τα αποτελέσματα που έχουν σε αυτές τις έρευνες συμφωνούν με την αρχική τους ιδέα. Μέσα από αυτή τη διαδικασία (που μπορεί να πάρει χρόνια) οι επιστήμονες καταφέρνουν να αποδείξουν τις αρχικές τους ιδέες ως σωστές. Αυτό σημαίνει ότι καταλήγουν σε μια θεωρία που μπορεί να εξηγήσει ικανοποιητικά κάποιο φαινόμενο.

Όμως, κάποιες φορές συμβαίνει τα αποτελέσματα ενός πειράματος να μην είναι εκείνα που περίμεναν οι επιστήμονες. Αυτό μπορεί να συμβεί όσο προσεκτικά και να κάνουν το πείραμα οι επιστήμονες όσες φορές και να το επαναλάβουν. Τότε θα πρέπει να αλλάξουν ή να διορθώσουν τις θεωρίες τους για να συμφωνούν περισσότερο με τα ερευνητικά αποτελέσματα.

Τα συμπεράσματα που θα βγάλουν οι επιστήμονες από τα αποτελέσματα του πειράματος θα τους βοηθήσουν να εξηγήσουν το φυσικό φαινόμενο που μελετούν. Αυτό δε σημαίνει ότι ανακαλύπτουν την απόλυτη αλήθεια για το φαινόμενο αυτό. Απλά δείχνει ότι η δική τους θεωρία εξηγεί το φυσικό φαινόμενο καλύτερα από άλλες θεωρίες. Στο μέλλον μπορεί να παρουσιαστεί μια άλλη θεωρία που να το εξηγεί ακόμα καλύτερα.

Οι επιστήμονες, λοιπόν, σκέφτονται ιδέες και θεωρίες τις οποίες θα πρέπει να στηρίζουν στα αποτελέσματα της δικής τους έρευνας και της έρευνας άλλων επιστημόνων. Χρειάζεται να δείχνουν ότι οι απόψεις και οι ιδέες τους είναι σωστές μέσα από πολλά πειράματα και έρευνες. Όταν λοιπόν έχουμε μια σειρά ερευνών που τα αποτελέσματά τους συμφωνούν με μια συγκεκριμένη ιδέα ή θεωρία, τότε μόνο μπορούμε να πούμε ότι έχουμε νέα γνώση στην επιστήμη.

WHAT IS THE ROLE OF EXPERIMENTS AND RESEARCH IN SCIENCE?

Scientists cannot just think of a smart idea or a new theory and present it as knowledge in science. When they think of a new idea or theory they need to search and find what other scientists know about the particular topic. They need to find what experiments and what research projects have been completed on the topic. They will subsequently design their own experiments in order to find out whether their new idea is correct. In other words they will examine whether their idea may explain the phenomenon they study.

Scientists will therefore do a lot of observations and conduct experiments and they will examine whether the results of their research support the idea they had in the first place. Through this procedure (that may take years) scientists prove the validity of their ideas. This means that they end up with a theory that can sufficiently explain a phenomenon.

Sometimes however, the results of an experiment are not the expected. This may happen no matter how carefully scientists conduct the experiment or how many times they repeat it. If this happens, then they will have to change or correct their theories in order to agree more with the research results.

Scientists' conclusions from the research results will help them explain the phenomenon they study. This does not mean that they discover the absolute truth about what they study. It simply manifests that their theory explains the particular phenomenon in nature more sufficiently than other theories. One other theory that may explain it even better may be presented in the future.

Scientists think of ideas and theories that they need to support with results from their own research and the research conducted by other scientists. They need to show that their views and ideas are correct through many experiments and research projects. It is only when the results of a series of research projects support a particular idea or theory that we may claim that we have new knowledge in science.

Appendix F

Refutation Text

Η ΓΝΩΣΗ ΣΤΗΝ ΕΠΙΣΤΗΜΗ ΑΛΛΑΖΕΙ Ή ΜΕΝΕΙ ΣΤΑΘΕΡΗ;

Όταν οι επιστήμονες θέλουν να περιγράψουν και να εξηγήσουν ένα φαινόμενο στη φύση τότε κάνουν διάφορες έρευνες και πειράματα. Μέσα από αυτά μπορεί να καταλήξουν σε κάποια αποτελέσματα και συμπεράσματα. Αν επαναλάβουν τα ίδια πειράματα και συνεχίζουν να βρίσκουν τα ίδια αποτελέσματα τότε μπορεί να καταλήξουν σε μια θεωρία. Μπορεί πάλι ίσως να επιβεβαιώσουν μια θεωρία που γνώριζαν από πριν. Έτσι λοιπόν οι θεωρίες στην επιστήμη δημιουργούνται για να περιγράψουν και να εξηγήσουν τα διάφορα φαινόμενα που συμβαίνουν γύρω μας. Όμως, οι διάφορες θεωρίες που δημιουργούνται μπορεί να αλλάξουν.

Παρόλα αυτά, πολλοί άνθρωποι πιστεύουν ότι η θεωρία που έχουμε για ένα συγκεκριμένο φαινόμενο δε θα αλλάξει. Σκέφτονται ίσως: «Γνωρίζουμε τι συμβαίνει, το έχουμε εξηγήσει. Έχουν γίνει τόσες έρευνες και πειράματα!». Στην πραγματικότητα όμως αυτό που πιστεύουν δεν είναι αλήθεια! Αυτό τους εμποδίζει να καταλάβουν τι είναι η επιστήμη, τα φαινόμενα που εξετάζει η επιστήμη και τους τρόπους της επιστημονικής έρευνας.

Οι επιστήμονες ερευνούν συνεχώς τα διάφορα φαινόμενα της φύσης. Μέσα από πολλές έρευνες και πειράματα ανακαλύπτουν νέα στοιχεία. Αυτά τα νέα στοιχεία πολλές φορές συμπληρώνουν όσα γνωρίζαμε μέχρι εκείνη τη στιγμή. Αυτό έχει ως αποτέλεσμα οι θεωρίες που έχουμε να περιγράφουν καλύτερα κάποιο φαινόμενο.

Άλλοτε πάλι, τα νέα στοιχεία δείχνουν ότι τα όσα γνωρίζαμε μέχρι εκείνη τη στιγμή ίσως να μην είναι και τόσο σωστά. Με βάση αυτά τα νέα στοιχεία μπορεί να γίνουν πολλές έρευνες. Εάν αυτές οι έρευνες δείχνουν κάθε φορά το ίδιο συμπέρασμα τότε μιλάμε για μια νέα θεωρία. Η νέα αυτή θεωρία μπορεί να εξηγεί καλύτερα το συγκεκριμένο φαινόμενο. Εάν συμβαίνει κάτι τέτοιο τότε η νέα θεωρία θα αλλάξει τα όσα γνωρίζαμε μέχρι εκείνη τη στιγμή.

Για παράδειγμα, στα πολύ παλιά χρόνια οι άνθρωποι πίστευαν ότι η γη είναι επίπεδη και ότι ο ήλιος κινείται γύρω από τη γη. Αυτή η θεωρία όμως τους εμπόδιζε να καταλάβουν πώς είναι δυνατόν όταν είναι μέρα στην Κίνα να είναι νύχτα στην Αγγλία! Οι συνεχείς έρευνες στην αστρονομία έδειξαν ότι, αντίθετα, η γη είναι σφαιρική και ότι είναι η γη που κινείται γύρω από τον ήλιο. Αυτή η νέα θεωρία εξήγησε καλύτερα την αλλαγή από μέρα σε νύχτα. Μας επέτρεψε επίσης να μάθουμε όσα ξέρουμε σήμερα για το ηλιακό μας σύστημα και τους άλλους πλανήτες. Η γνώση στην επιστήμη λοιπόν αλλάζει όταν μια νέα θεωρία μπορεί να εξηγήσει καλύτερα κάποιο φαινόμενο.

DOES KNOWLEDGE IN SCIENCE CHANGE OR REMAINS STABLE?

When scientists want to describe and explain a phenomenon in nature they do research and conduct different experiments. Through their research and experiments they derive results and conclusions. If they repeat the same experiments and continue to find the same results, then they may end up with a theory. Alternatively, they could confirm an existing theory.

Thus, the different theories in science are developed in order to describe and explain the various phenomena that occur in our world. However, the different theories that are developed could change. *However, many people believe that existing theory about a particular phenomenon it is not going to change. They may think: "We know how the phenomenon occurs, we have explained it. There have been so many research studies and experiments!". What these people believe however is not true. What these people believe makes it hard for them to understand what science is, the phenomena it investigates and the means of scientific research.* Scientists continuously investigate various phenomena in nature. Through numerous research projects and experiments they discover new evidence. This new evidence may extend our knowledge up to that point. As a result, existing theories describe phenomena more adequately.

New evidence may indicate however, that our existing knowledge may not be as valid as we thought it was. This new evidence may lead to new research efforts. If these research studies show repeatedly the same conclusions, then we may have a new theory. If this happens, then the new theory will change our existing knowledge. *For instance, in the old times people believed that the earth was flat and that the sun orbited around it. This theory however, prevented them from understanding that when it is daytime in China is nighttime in Britain. Continuous research in astronomy indicated that the earth was a sphere and that it was the earth that orbited around the sun. This new theory explained better the day-night cycle and it helped us to find out everything we nowadays know about the solar system and the planets.*

ΣΧΕΤΙΖΟΝΤΑΙ ΟΙ ΓΝΩΣΕΙΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ Ή ΕΙΝΑΙ ΑΣΧΕΤΕΣ ΜΕΤΑΞΥ ΤΟΥΣ;

Η γνώση στην επιστήμη δημιουργείται μέσα από την εργασία που κάνουν οι επιστήμονες. Αρκετά συχνά, μέσα από τις διάφορες έρευνες και τα πειράματα που κάνουν, καταλήγουν σε νέα γνώση.

Οι γνώσεις στην επιστήμη δεν είναι ξεκομμένες η μία από την άλλη, αλλά συνδέονται. Παρόλα αυτά πολλοί άνθρωποι πιστεύουν ότι η γνώση στην επιστήμη για ένα θέμα δεν μπορεί να έχει σχέση με τη γνώση σε κάποιο άλλο θέμα. Έτσι λοιπόν μπορεί να αναρωτιούνται: «Τι σχέση μπορεί να έχουν για παράδειγμα οι γνώσεις μας για τον ηλεκτρισμό με την έρευνα για τη θεραπεία ασθενειών;». Και δεν μπορούν να καταλάβουν πώς είναι δυνατόν οι γιατροί να χρησιμοποιούν τον ηλεκτρισμό για να βοηθήσουν έναν άνθρωπο που έχει πάθει καρδιακό επεισόδιο και να κάνουν την καρδιά του να ξαναρχίσει να χτυπάει.

Οι επιστήμονες, λοιπόν, για να κάνουν ένα πείραμα ή μια έρευνα δεν ξεκινούν από το μηδέν. Πριν κάνουν το πείραμά τους φροντίζουν να ενημερώνονται καλά για τη γνώση που υπάρχει για το συγκεκριμένο θέμα μέχρι εκείνη τη στιγμή. Συμβαίνει πολύ συχνά άλλοι επιστήμονες να έχουν ερευνήσει κάτι παρόμοιο. Όταν θα τελειώσει το πείραμα οι επιστήμονες πιθανόν να μάθουν κάτι καινούργιο. Έτσι, αυτό το καινούργιο θα έχει κάποια σχέση, μικρή ή μεγάλη με τα αποτελέσματα άλλων πειραμάτων για το ίδιο θέμα. Μπορεί πάλι να έχει κάποια σχέση με παρόμοιο θέμα ή με κάποιο άλλο θέμα που μπορεί να φαίνεται άσχετο.

Έτσι λοιπόν οι γνώσεις στην επιστήμη συσχετίζονται μεταξύ τους με πάρα πολλούς τρόπους. Πολλές φορές αν δεν καταλάβουμε τι σχέση υπάρχει μεταξύ των διαφορετικών κομματιών γνώσης μπορεί να μην μπορούμε να κατανοήσουμε ένα φυσικό φαινόμενο. Αν λοιπόν οι επιστήμονες πίστευαν ότι κάθε κομμάτι γνώσης είναι ξεχωριστό, τότε δε θα είχαμε σήμερα γυαλιά οράσεως! Οι φυσικοί γνώριζαν ότι όταν ακτίνες φωτός περνούν μέσα από φακούς αλλάζει η πορεία τους. Μέσα από τους συγκλίνοντες φακούς οι ακτίνες έρχονται πιο κοντά η μια στην άλλη. Οι οφθαλμίατροι γνώριζαν ότι το ανθρώπινο μάτι έχει φακό που συμπεριφέρεται με τον ίδιο τρόπο όπως και οι συγκλίνοντες φακοί. Ο φακός στο ανθρώπινο μάτι συγκεντρώνει τις ακτίνες στο κατάλληλο νεύρο για να μπορούμε να βλέπουμε. Γνώριζαν επίσης πως προβλήματα στο φακό του ματιού δημιουργούν τη μυωπία, την πρεσβυωπία κ.α. Λόγω των προβλημάτων αυτών οι ακτίνες δε συγκεντρώνονται πάνω στο νεύρο του ματιού με αποτέλεσμα ο άνθρωπος να μη βλέπει καλά. Αν όμως οι επιστήμονες δε συνέδεαν τη γνώση των φυσικών και των οφθαλμίατρων, τότε κανείς δε θα σκεφτόταν να φτιάξει γυαλιά οράσεως. Δηλαδή να δημιουργήσει γυαλιά με τον κατάλληλο φακό για όσους έχουν πρόβλημα με τα μάτια τους, ώστε να διορθωθεί το πρόβλημα και να βλέπουν καλά.

Οι επιστήμονες λοιπόν για να βγάλουν τα σωστά συμπεράσματα από τα πειράματά τους θα πρέπει να συνδέσουν τις γνώσεις μεταξύ τους. Χρειάζεται δηλαδή να εξηγήσουν ποια σχέση υπάρχει μεταξύ του καινούργιου (που έχουν μάθει από το δικό τους πείραμα) και της γνώσης που υπήρχε ήδη μέχρι εκείνη τη στιγμή. Η σύνδεση των γνώσεων είναι αυτή που θα τους βοηθήσει να κατανοήσουν και να εξηγήσουν καλύτερα τα διάφορα φαινόμενα που μελετούν.

Από όλα αυτά καταλαβαίνουμε ότι στην επιστήμη τίποτα δεν είναι ξεκομμένο. Τα βιβλία της επιστήμης που διαβάζουμε στο σχολείο είναι χωρισμένα σε ενότητες για να μας είναι πιο εύκολο να μάθουμε. Στην πραγματικότητα, όμως, αυτά που μαθαίνουμε σε μια ενότητα, συνδέονται με αυτά που μάθαμε σε άλλες ενότητες και με αυτά που θα μάθουμε παρακάτω. Κάθε τι καινούργιο συνδέεται, έχει σχέση, δηλαδή, με τα όσα γνωρίζαμε για το συγκεκριμένο θέμα ή και για άλλα θέματα μέχρι εκείνη τη στιγμή.

ARE DIFFERENT PARTS OF KNOWLEDGE IN SCIENCE INTERRELATED OR UNRELATED TO EACH OTHER?

Knowledge in science derives from scientists' work. Through research and experiments scientists often end up with new knowledge.

Parts of knowledge in science are interrelated. *There are people however, who believe that knowledge in science for a particular topic cannot be related to knowledge about a different topic. They therefore wonder for instance: "How is knowledge about electricity related to knowledge about curing illnesses?". As a result, they cannot understand how doctors use electricity to help, for instance, a person who endured a heart attack in order to make his heart pump again.*

In order to conduct an experiment or complete a research project, scientists do not start from zero. Before they conduct their experiments they make sure to get informed about existing knowledge on the particular topic. Other scientists may have researched a similar topic. On the completion of the experiment, scientists may find out something new. Therefore, this new piece of knowledge may be related to a large or a small extent to the results of other experiments on the same topic. It could even be related to a similar topic or to another topic that seems totally different.

Different parts of knowledge in science are therefore interrelated via many different ways. We may often have a hard time trying to understand a natural phenomenon, without understanding first the relationship between the different parts of knowledge. *If scientists, believed that different parts of knowledge are unrelated to each other contact glasses would not have existed today. Physicists knew that light diverges as it passes through lenses. Ophthalmologists knew that there is a lens in our eye that acts in the same way as convex lenses. The lens in our eyes focuses light on a particular optical neuron in order for us to be able to see. Ophthalmologists also knew that problems on the lens of the eye result into eye problems like myopia or presbyopia. Due to such vision difficulties, light rays do not focus on the right optical neuron and as a result people who have such problems do not see well. Contact glasses would not have existed if scientists had not connected physicists' and ophthalmologists' knowledge. No one would have thought in other words, to design glasses with the right lenses for those who have eye problems, in order to fix their problem and help them see well*. As a result, scientists need to establish the connections between the different parts of knowledge in order to derive the right conclusions from their experiments. In other words, they need to explain how the new piece of knowledge (derived from their own experiments) relates to existing knowledge. Interrelatedness of knowledge will help them better understand and explain the different phenomena they examine.

As a result, everything in science is interrelated. *School science books are organized in units in order to help us learn more easily. In fact, what we learn in a new unit is related to things we learnt in previous units or to things we will learn in subsequent units.* Every new piece of knowledge connects or relates to everything we knew for the particular topic or other topics until that point in time.

<u>ΠΟΙΟΣ ΕΙΝΑΙ Ο ΡΟΛΟΣ ΤΩΝ ΙΔΕΩΝ ΤΟΥ ΕΠΙΣΤΗΜΟΝΑ ΣΤΗΝ ΕΡΕΥΝΑ;</u>

Οι επιστήμονες ενημερώνονται για τις γνώσεις που ήδη υπάρχουν για ένα φαινόμενο πριν σχεδιάσουν και κάνουν ένα δικό τους πείραμα ή μια παρατήρηση. Όμως για να σχεδιάσουν σωστά το δικό τους πείραμα, θα πρέπει να σκεφτούν τι σημαίνουν οι γνώσεις που ήδη υπάρχουν και αν εξηγούν καλά το φαινόμενο ή όχι. Θα πρέπει ακόμα να σκεφτούν, με ποιες άλλες γνώσεις συνδέονται οι γνώσεις που υπάρχουν για το συγκεκριμένο φαινόμενο. Θα πρέπει δηλαδή να καταλαβαίνουν καλά ποια είναι η γνώση που υπάρχει για το θέμα που θέλουν να μελετήσουν.

Ένας καλός επιστήμονας όμως, δε φτάνει να ξέρει καλά τις γνώσεις που έχουν ανακαλύψει οι υπόλοιποι επιστήμονες. Θα πρέπει να έχει νέες ιδέες και να σχεδιάζει τα δικά του πειράματα ή έρευνες για να ελέγξει αν οι ιδέες του ισχύουν. Έτσι λοιπόν, κάθε έρευνα στην επιστήμη στηρίζεται σε προηγούμενες γνώσεις. Η έρευνα στηρίζεται όμως και στον τρόπο με το οποίο σκέφτονται οι επιστήμονες για αυτές τις γνώσεις. Δηλαδή, στις ιδέες που έχουν οι επιστήμονες!

Τα αποτελέσματα των πειραμάτων δεν είναι από μόνα τους γνώση. Όταν οι επιστήμονες ολοκληρώσουν ένα πείραμα ή μια παρατήρηση θα πρέπει να σκεφτούν τι σημαίνουν τα αποτελέσματά τους. Με αυτό τον τρόπο θα βγάλουν συμπεράσματα από τα αποτελέσματά τους και θα εξηγήσουν με ποιο τρόπο οι ιδέες τους, που οδήγησαν στο πείραμα, εξηγούν το φαινόμενο που μελέτησαν. Για να βγάλουν τα σωστά συμπεράσματα χρειάζεται ακόμα να σκεφτούν και με ποιες άλλες προηγούμενες γνώσεις συνδέονται αυτά που ανακάλυψαν. Η επιστημονική γνώση, λοιπόν, είναι η ερμηνεία των αποτελεσμάτων. Με άλλα λόγια ο τρόπος που οι επιστήμονες σκέφτονται και εξηγούν τα αποτελέσματα του πειράματος και βγάζουν τα συμπεράσματά τους.

Παρόλο που πολλοί άνθρωποι πιστεύουν ότι οι επιστήμονες απλώς ανακαλύπτουν τι υπάρχει και τι συμβαίνει στη φύση, αυτό δεν είναι αλήθεια! Οι άνθρωποι που πιστεύουν κάτι τέτοιο δεν μπορούν να καταλάβουν ότι ο κάθε επιστήμονας εξηγεί τα αποτελέσματα πειραμάτων και ερευνών και βγάζει τα δικά του συμπεράσματα σύμφωνα με τις δικές του ιδέες και θεωρίες. Σκεφτείτε, για παράδειγμα, δύο επιστήμονες να παρατηρούν το ίδιο φαινόμενο: τον ήλιο να εμφανίζεται κάθε πρωί σε ένα συγκεκριμένο σημείο του ορίζοντα – αυτό που ονομάζουμε ανατολή. Αυτό είναι το αποτέλεσμα της παρατήρησης και των δύο. Ο ένας επιστήμονας λέει ότι το αποτέλεσμα αυτό σημαίνει ότι ο ήλιος κινείται γύρω από τη γη.

Ο δεύτερος, όμως, επιστήμονας λέει ότι αυτό το αποτέλεσμα σημαίνει ότι η γη κινείται γύρω από τον άξονά της και έτσι μπορούμε εμείς να βλέπουμε το ήλιο ξανά στην ανατολή μετά από μια πλήρη περιστροφή της γης. Αυτοί οι δύο επιστήμονες, λοιπόν, εξηγούν το ίδιο φαινόμενο, το ίδιο αποτέλεσμα, με εντελώς διαφορετικούς τρόπους. Έχουν, δηλαδή, διαφορετικές θεωρίες και τρόπους σκέψης! Σήμερα, όπως γνωρίζουμε, οι άλλοι επιστήμονες θα συμφωνούσαν περισσότερο με τη θεωρία του δεύτερου επιστήμονα. Και είναι αυτή η θεωρία που αποτελεί επιστημονική γνώση – όχι το γεγονός ότι ο ήλιος εμφανίζεται κάθε πρωί στην ανατολή.

WHAT IS THE ROLE OF SCIENTISTS' IDEAS IN SCIENCE?

Before scientists conduct an experiment they get informed about existing knowledge. In order to design their own experiment in the right way, they need to think well what existing knowledge tells us and whether it explains the phenomenon well. They also need to think to what other knowledge about the particular topic existing knowledge connects to. In other words, scientists need to understand well existing knowledge about the topic they would like to study.

It is not enough for good scientists however, to merely know the knowledge discovered by other scientists. Good scientists need to think of new ideas and design their own experiments or research in order to examine the validity of their ideas. Research in science builds therefore from previous knowledge. It is noteworthy however, that research also depends a lot on the way scientists think about knowledge. In other words, research depends on scientists' ideas!

A research result cannot be considered knowledge in and of itself. When scientists complete an experiment or a scientific observation they need to think what is the meaning of their results. This way they will derive conclusions from their results and they will explain how their ideas that originated the experiment in the first place explain the particular phenomenon they studied. Scientific knowledge is therefore the interpretation of the results. In other words, it is the way scientists think and explain experimental results and derive conclusions. *Although many people believe that scientists just discover natural phenomena and how they occur, this is not true. People with such beliefs cannot understand that every scientist explains research or experiment results on the basis of his/hers own ideas and theories. Consider for instance, two scientists who observe the same phenomenon: the sun rising everyday from a particular point in the horizon (the east). This is the result of the observation of both scientists. One of the two scientists says that this observation means that the sun orbits around the earth. The other scientist says that this observation means that the earth orbits around itself and we can thus see the sun in the east after one full orbit of earth. These two scientists explain the same phenomenon with totally different ways. They have therefore different theories and ways of thinking. Nowadays, scientists would agree more with the second scientist's theory. This theory represents scientific knowledge-not the observation that the sun rises everyday from the east.*

ΠΟΙΟΣ ΕΙΝΑΙ Ο ΡΟΛΟΣ ΤΟΥ ΠΕΙΡΑΜΑΤΟΣ ΚΑΙ ΤΗΣ ΕΡΕΥΝΑΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ;

Οι επιστήμονες δεν μπορούν απλά να σκεφτούν μια έξυπνη ιδέα ή μια καινούργια θεωρία και να την παρουσιάσουν ως νέα γνώση στην επιστήμη. Παρόλο που μερικοί άνθρωποι πιστεύουν ότι επειδή οι επιστήμονες είναι επιστήμονες μπορούν να λένε έτσι απλά τις ιδέες τους χωρίς να τις υποστηρίζουν αυτό δεν είναι αλήθεια! Ούτε είναι αλήθεια ότι οι ιδέες των επιστημόνων χωρίς στοιχεία που να δείχνουν ότι είναι σωστές μπορεί να αποτελούν νέα γνώση στην επιστήμη. Γιατί, οι επιστήμονες χρειάζεται να υποστηρίζουν τις ιδέες τους με πειράματα και έρευνες.

Οι άνθρωποι που δεν το καταλαβαίνουν αυτό, στην πραγματικότητα δεν μπορούν να καταλάβουν ούτε τη σημασία που έχουν οι έρευνες και τα πειράματα ούτε και τις μεθόδους έρευνας στην επιστήμη. Δεν μπορούν να καταλάβουν, δηλαδή, ότι όταν οι γιατροί λένε ότι «ο πονόλαιμος οφείλεται σε μικρόβια», αυτό είναι το συμπέρασμα που έβγαλαν μέσα από διάφορες έρευνες. Μελετώντας δηλαδή ανθρώπους με πονόλαιμο και χωρίς πονόλαιμο, που ζούσαν στο κρύο ή στη ζέστη, που έπιναν ζεστό τσάι ή που δεν έπιναν ζεστό τσάι. Σε μια ολόκληρη σειρά ερευνών παρατήρησαν με το μικροσκόπιο μικρόβια στο λαιμό και στο σάλιο των ανθρώπων που είχαν πονόλαιμο σε διάφορες συνθήκες. Είτε αυτοί έπιναν τσάι είτε όχι, είτε έμεναν μέσα στο σπίτι τους στη ζέστη είτε εργάζονταν όλη μέρα έξω στο κρύο.

Οι επιστήμονες λοιπόν όταν σκεφτούν μια νέα ιδέα ή θεωρία θα πρέπει πρώτα να ψάξουν και να βρουν τι γνωρίζουν οι υπόλοιποι επιστήμονες για το συγκεκριμένο θέμα. Θα πρέπει να βρουν τι πειράματα και τι έρευνες έχουν γίνει για αυτό το θέμα. Στη συνέχεια θα σχεδιάσουν τα δικά τους πειράματα με σκοπό να βρουν αν η αρχική τους ιδέα είναι σωστή. Θα ελέγξουν δηλαδή αν η ιδέα τους μπορεί να εξηγήσει το φαινόμενο που μελετούν.

Έτσι λοιπόν θα κάνουν πολλές παρατηρήσεις και πειράματα και θα εξετάζουν κάθε φορά αν τα αποτελέσματα που έχουν σε αυτές τις έρευνες συμφωνούν με την αρχική τους ιδέα. Μέσα από αυτή τη διαδικασία (που μπορεί να πάρει χρόνια), οι επιστήμονες καταφέρνουν να αποδείξουν τις αρχικές τους ιδέες ως σωστές. Αυτό σημαίνει ότι καταλήγουν σε μια θεωρία που μπορεί να εξηγήσει ικανοποιητικά κάποιο φαινόμενο.

Όμως, κάποιες φορές συμβαίνει τα αποτελέσματα ενός πειράματος να μην είναι εκείνα που περίμεναν οι επιστήμονες. Αυτό μπορεί να συμβεί όσο προσεκτικά και να κάνουν το πείραμα όσες φορές και να το επαναλάβουν. Τότε θα πρέπει να αλλάξουν ή να διορθώσουν τις θεωρίες τους για να συμφωνούν περισσότερο με τα ερευνητικά αποτελέσματα.

Τα συμπεράσματα που θα βγάλουν οι επιστήμονες από τα αποτελέσματα του πειράματος θα τους βοηθήσουν να εξηγήσουν το φυσικό φαινόμενο που μελετούν. Αυτό δε σημαίνει ότι ανακαλύπτουν την απόλυτη αλήθεια για το φαινόμενο αυτό. Απλά δείχνει ότι η δική τους θεωρία εξηγεί το φυσικό φαινόμενο καλύτερα από άλλες θεωρίες. Στο μέλλον μπορεί να παρουσιαστεί μια άλλη θεωρία που να το εξηγεί ακόμα καλύτερα.

Μερικοί άνθρωποι, παρόλο που καταλαβαίνουν ότι οι ιδέες και οι θεωρίες θα πρέπει να υποστηρίζονται από ερευνητικά αποτελέσματα, θεωρούν ότι μια παρατήρηση ή ότι ένα και μόνο πείραμα που να δείχνει αυτή την ιδέα σωστή είναι αρκετό. Αυτό δεν είναι αλήθεια, και το βλέπουμε σχεδόν καθημερινά. Για σκεφτείτε λίγο την περίπτωση του καφέ: κάποιες έρευνες έδειξαν ότι δεν μας κάνει καλό να πίνουμε καφέ και άλλες έδειξαν ότι δεν κάνει κακό ή ότι ακόμα κάνει και καλό. Μια μόνο έρευνα δεν είναι αρκετή για να θεωρήσουμε τα αποτελέσματα και τα συμπεράσματα στα οποία οδηγεί ως νέα επιστημονική γνώση.

Οι επιστήμονες, λοιπόν, σκέφτονται ιδέες και θεωρίες τις οποίες θα πρέπει να στηρίζουν στα αποτελέσματα της δικής τους έρευνας και της έρευνας άλλων επιστημόνων. Χρειάζεται να δείχνουν ότι οι απόψεις και οι ιδέες τους είναι σωστές μέσα από πολλά πειράματα και έρευνες. Όταν λοιπόν έχουμε μια σειρά ερευνών που τα αποτελέσματά τους συμφωνούν με μια συγκεκριμένη ιδέα ή θεωρία, τότε μόνο μπορούμε να πούμε ότι έχουμε νέα γνώση στην επιστήμη.

WHAT IS THE ROLE OF EXPERIMENTS AND RESEARCH IN SCIENCE?

Scientists cannot just think of a smart idea or a new theory and present it as knowledge in science. *Although there are people however who believe that scientists can present their ideas without justifying them, simply because they are scientists, what these people believe is not true. It is also not true that scientists' ideas without any evidence supporting their validity may represent new knowledge in science. This is because scientists need to support their ideas with experiments and research.*

In fact, people who cannot understand this, can neither realize the importance of research and experiments nor understand the methods of research in science. For instance, they cannot understand that when doctors say that "microbes cause soar throat", this statement represents the conclusion they derived from different research projects. In other words, studying people with or without a sore throat, people who lived in cold or warm weather conditions, who used to drink hot tea or who did not drink hot tea. In a whole series of research projects they observed with their microscopes microbes in the throat and the saliva of people with a sore throat under different situations: whether they drank tea or not, whether they stayed indoors or worked outdoors in the cold for the whole day.

When scientists think of a new idea or theory they need to search and find what other scientists know about the particular topic. They need to find what experiments and what research projects have been completed on the topic. They will subsequently design their own experiments in order to find out whether their new idea is correct. In other words they will examine whether their idea may explain the phenomenon they study.

Scientists will therefore do a lot of observations and conduct experiments and they will examine whether the results of their research support the idea they had in the first place. Through this procedure (that may take years) scientists prove the validity of their ideas. This means that they end up with a theory that can sufficiently explain a phenomenon.

Sometimes however, the results of an experiment are not the expected. This may happen no matter how carefully scientists conduct the experiment or how many times they repeat it. If this happens, then they will have to change or correct their theories in order to agree more with the research results.

Scientists' conclusions from the research results will help them explain the phenomenon they study. This does not mean that they discover the absolute truth about what they study. It simply manifests that their theory explains the particular phenomenon in nature more sufficiently than other theories. One other theory that may explain it even better may be presented in the future.

There are people however, who although they understand that ideas and theories need to be supported by research evidence, they tend to think that one observation or only one experiment that shows that the idea is true is sufficient. This is not true however. Consider the case of coffee. There is research that indicates that drinking coffee does not help our body, but there is also research that shows that caffeine intake cannot do any harm, and may even benefit our body.

Scientists think of ideas and theories that they need to support with results from their own research and the research conducted by other scientists. They need to show that their views and ideas are correct through many experiments and research projects. It is only when the results of a series of research projects support a particular idea or theory that we may claim that we have new knowledge in science.

Appendix G

Analogy Text

<u>Η ΓΝΩΣΗ ΣΤΗΝ ΕΠΙΣΤΗΜΗ ΑΛΛΑΖΕΙ Ή ΜΕΝΕΙ ΣΤΑΘΕΡΗ;</u>

Όταν οι επιστήμονες θέλουν να περιγράψουν και να εξηγήσουν ένα φαινόμενο στη φύση τότε κάνουν διάφορες έρευνες και πειράματα. Μέσα από αυτά μπορεί να καταλήξουν σε κάποια αποτελέσματα και συμπεράσματα. Αν επαναλάβουν τα ίδια πειράματα και συνεχίζουν να βρίσκουν τα ίδια αποτελέσματα τότε μπορεί να καταλήξουν σε μια θεωρία. Μπορεί πάλι ίσως να επιβεβαιώσουν μια θεωρία που γνώριζαν από πριν. Έτσι λοιπόν οι θεωρίες στην επιστήμη δημιουργούνται για να περιγράψουν και να εξηγήσουν τα διάφορα φαινόμενα που συμβαίνουν γύρω μας. Όμως, οι διάφορες θεωρίες που δημιουργούνται μπορεί να αλλάξουν.

Για να καταλάβεις αυτή την αλλαγή που συμβαίνει στις γνώσεις στην επιστήμη, σκέψου ένα παράδειγμα από την καθημερινή ζωή. Σκέψου για παράδειγμα πόσο πολύ άλλαξαν τα παιχνίδια από τον καιρό των γονιών ή παππούδων σας μέχρι σήμερα. Αν τους ρωτήσετε θα σας πουν ότι έπαιζαν με αντικείμενα που έβρισκαν στη φύση ή έφτιαχναν μόνοι τους. Τα αγόρια έπαιζαν με μπάλες που έφτιαχναν με παλιά υφάσματα και τα κορίτσια με κούκλες που έφτιαχναν με παλιά υφάσματα. Σήμερα όμως τα παιχνίδια είναι τόσο διαφορετικά. Τα ηλεκτρονικά είναι τα αγαπημένα παιχνίδια πολλών παιδιών. Εκεί που τα παιδιά στο παρελθόν έπαιζαν με μια υφασμάτινη μπάλα, τώρα τα παιδιά παίζουν με ηλεκτρονικά παιχνίδια. Μέσα από παιχνίδια όπως είναι για παράδειγμα το PSP μπορούν να παίζουν σε αγώνες ποδοσφαίρου και να παίρνουν τους ρόλους αγαπημένων τους παικτών.

Οι επιστήμονες ερευνούν συνεχώς τα διάφορα φαινόμενα της φύσης. Μέσα από πολλές έρευνες και πειράματα ανακαλύπτουν νέα στοιχεία. Αυτά τα νέα στοιχεία πολλές φορές συμπληρώνουν όσα γνωρίζαμε μέχρι εκείνη τη στιγμή. Αυτό έχει ως αποτέλεσμα οι θεωρίες που έχουμε να περιγράφουν καλύτερα κάποιο φαινόμενο. Άλλοτε πάλι, τα νέα στοιχεία δείχνουν ότι τα όσα γνωρίζαμε μέχρι εκείνη τη στιγμή ίσως να μην είναι και τόσο σωστά. Με βάση αυτά τα νέα στοιχεία μπορεί να γίνουν πολλές έρευνες. Εάν αυτές οι έρευνες δείχνουν κάθε φορά το ίδιο συμπέρασμα τότε μιλάμε για μια νέα θεωρία. Η νέα αυτή θεωρία μπορεί να εξηγεί καλύτερα το συγκεκριμένο φαινόμενο. Εάν συμβαίνει κάτι τέτοιο τότε θα αλλάξει τα όσα γνωρίζαμε μέχρι εκείνη τη στιγμή.

Ποιος θα μπορούσε να φανταστεί ότι κάποτε θα δημιουργούνταν αυτοκίνητα που να μη χρειάζονται βενζίνη αλλά να λειτουργούν με ηλεκτρισμό; Οι επιστήμονες προβλέπουν ότι σε λίγα χρόνια το πετρέλαιο θα εξαντληθεί. Έπρεπε επομένως εφόσον το πετρέλαιο στο μέλλον θα εξαντληθεί να βρεθούν άλλα μέσα για να μετακινούμαστε. Τα διάφορα μέσα που χρησιμοποιεί ο άνθρωπος αλλάζουν για να εξυπηρετήσουν τις ανάγκες του καλύτερα. Με τον ίδιο τρόπο και η γνώση στην επιστήμη αλλάζει όταν μια νέα θεωρία μπορεί να εξηγήσει καλύτερα κάποιο φαινόμενο.

DOES KNOWLEDGE IN SCIENCE CHANGE OR REMAINS STABLE?

When scientists want to describe and explain a phenomenon in nature they do research and conduct different experiments. Through their research and experiments they derive results and conclusions. If they repeat the same experiments and continue to find the same results, then they may end up with a theory. Alternatively, they could confirm an existing theory.

Thus, the different theories in science are developed in order to describe and explain the various phenomena that occur in our world. However, the different theories that are developed could change. *To understand this change that occurs in knowledge in science consider an everyday example. Think about how much toys have changed since the time your parents' or grandparents were young. If you ask them they will tell you that they played with toys that they found in nature or with toys they had handcrafted. Boys used to play with balls that they used to make from old cloth and the girls used to play with dolls they handcrafted from old cloth. However, nowadays toys are so much different. Electronic games are most children's favorites. In the past kids used to play with handmade toys, nowadays kids play with electronic games. Through games like PSP they can take part in football games and enact their favorite players.* Scientists continuously investigate various phenomena in nature. Through numerous research projects and experiments they discover new evidence. This new evidence may extend our knowledge up to that point. As a result, existing theories describe phenomena more adequately.

New evidence may indicate however, that our existing knowledge may not be as valid as we thought it was. This new evidence may lead to new research efforts. If these research studies show repeatedly the same conclusions, then we may have a new theory. If this happens, then the new theory will change our existing knowledge. *Who could ever think that there would be a time when cars would function with electricity instead of gasoline? Scientists predict that petrol would become extinct in a few years. New transportation means needed thus to be developed. Transportation means change when they may service people better.*

ΣΧΕΤΙΖΟΝΤΑΙ ΟΙ ΓΝΩΣΕΙΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ Ή ΕΙΝΑΙ ΑΣΧΕΤΕΣ ΜΕΤΑΞΥ ΤΟΥΣ;

Η γνώση στην επιστήμη δημιουργείται μέσα από την εργασία που κάνουν οι επιστήμονες. Αρκετά συχνά, μέσα από τις διάφορες έρευνες και τα πειράματα που κάνουν, καταλήγουν σε νέα γνώση.

Οι γνώσεις στην επιστήμη δεν είναι ξεκομμένες η μία από την άλλη, αλλά συνδέονται. Σκέψου για παράδειγμα πόσο μεγάλη σχέση έχουν μεταξύ τους οι κανόνες ενός παιχνιδιού. Στο ομαδικό παιχνίδι «μήλο» ή «γερμανικό» υπάρχουν αρκετοί κανόνες που πρέπει να γνωρίζεις καλά. Πρέπει επίσης να γνωρίζεις καλά πώς σχετίζονται μεταξύ τους οι κανόνες. Για παράδειγμα, πρέπει να ξέρεις τι ρόλο παίζουν οι φύλακες, τι θα γίνει στην περίπτωση που οι φύλακες κτυπήσουν κάποιο παίκτη, ή όταν η μπάλα πέσει στο έδαφος κλπ. Σε αυτό το παιχνίδι είναι σημαντικό να ξέρεις τι θα γίνει στην περίπτωση που οι φύλακες κτυπήσουν κάποιο παίκτη που ήδη έχει κερδίσει «μήλο».

Οι επιστήμονες, λοιπόν, για να κάνουν ένα πείραμα ή μια έρευνα δεν ξεκινούν από το μηδέν. Πριν κάνουν το πείραμά τους φροντίζουν να ενημερώνονται καλά για τη γνώση που υπάρχει για το συγκεκριμένο θέμα μέχρι εκείνη τη στιγμή. Συμβαίνει πολύ συχνά άλλοι επιστήμονες να έχουν ερευνήσει κάτι παρόμοιο. Όταν θα τελειώσει το πείραμα οι επιστήμονες πιθανόν να μάθουν κάτι καινούργιο. Έτσι, αυτό το καινούργιο θα έχει κάποια σχέση, μικρή ή μεγάλη με τα αποτελέσματα άλλων πειραμάτων για το ίδιο θέμα. Μπορεί πάλι να έχει κάποια σχέση με παρόμοιο θέμα ή ακόμα και με κάποιο άλλο θέμα που μπορεί να φαίνεται άσχετο.

Έτσι λοιπόν οι γνώσεις στην επιστήμη συσχετίζονται μεταξύ τους με πάρα πολλούς τρόπους. Πολλές φορές αν δεν καταλάβουμε τι σχέση υπάρχει μεταξύ των διαφορετικών κομματιών γνώσης μπορεί να μην μπορούμε να κατανοήσουμε ένα φυσικό φαινόμενο. Όταν είμαστε άρρωστοι και επισκεπτόμαστε το γιατρό παρατηρούμε ότι για να καταλάβει ο γιατρός ποια ασθένεια μας ταλαιπωρεί, μας εξετάζει σε διάφορα σημεία του σώματός μας. Εξετάζει συνήθως το λαιμό, τους πνεύμονες, τα αυτιά μας κλπ. Μόνο όταν τα συνδυάσει όλα μεταξύ τους, μπορεί να αποφασίσει για την ασθένεια που έχουμε, ώστε να μας δώσει και τα σωστά φάρμακα.

Με τον ίδιο τρόπο και οι επιστήμονες για να βγάλουν τα σωστά συμπεράσματα από τα πειράματά τους θα πρέπει να συνδέσουν τις γνώσεις μεταξύ τους. Χρειάζεται δηλαδή να εξηγήσουν ποια σχέση υπάρχει μεταξύ του καινούργιου που έχουν μάθει από το δικό τους πείραμα και της γνώσης που υπήρχε ήδη μέχρι εκείνη τη στιγμή. Η σύνδεση των γνώσεων είναι αυτή που θα τους βοηθήσει να κατανοήσουν και να εξηγήσουν καλύτερα τα διάφορα φαινόμενα που μελετούν.

Από όλα αυτά καταλαβαίνουμε ότι στην επιστήμη τίποτα δεν είναι ξεκομμένο. Σκέψου το διάλειμμα στο σχολείο, όπου κάποια παιδιά μπορεί να τσακωθούν. Η Χριστίνα π.χ. λέει στα υπόλοιπα παιδιά της τάξης να μην κάνουν παρέα με τη Μαρία. Το διάλειμμα η Μαρία βρίζει τη Χριστίνα. Η Χριστίνα παραπονιέται ότι η Μαρία τη βρίζει και καταγγέλλει τη Μαρία στη δασκάλα της. Για να αποφασίσει η δασκάλα ποιο από τα δύο κορίτσια φταίει για αυτό που έγινε θα πρέπει να μάθει όλη την ιστορία και να δει ότι η Μαρία έβρισε μετά που η Χριστίνα έστρεψε όλη την τάξη εναντίον της. Μόνο έτσι θα βγάλει το σωστό συμπέρασμα. Κάθε τι καινούργιο συνδέεται, έχει σχέση, δηλαδή, με τα όσα γνωρίζαμε για το συγκεκριμένο θέμα ή και για άλλα θέματα μέχρι εκείνη τη στιγμή.

ARE DIFFERENT PARTS OF KNOWLEDGE IN SCIENCE INTERRELATED OR UNRELATED TO EACH OTHER?

Knowledge in science derives from scientists' work. Through research and experiments scientists often end up with new knowledge.

Parts of knowledge in science are interrelated. *Consider, for instance, the rules of a game and the extent to which they can be related to each other. To take part in the group game "milo" for example, there is a number of rules that you need to know very well. You also need to know how these different rules relate to each other. For instance, you need to know the role of the 'guardians', what happens when 'guardians' hit a player or when the ball hits the ground, etc. It is important that in this game you know what happens when 'guardians' hit a player who has previously earned an 'apple'.*

In order to conduct an experiment or complete a research project, scientists do not start from zero. Before they conduct their experiments they make sure to get informed about existing knowledge on the particular topic. Other scientists may have researched a similar topic. On the completion of the experiment, scientists may find out something new. Therefore, this new piece of knowledge may be related to a large or a small extent to the results of other experiments on the same topic. It could even be related to a similar topic or to another topic that seems totally different.

Different parts of knowledge in science are therefore interrelated via many different ways. We may often have a hard time trying to understand a natural phenomenon, without understanding first the relationship between the different parts of knowledge. *We know that when we are sick and visit the doctor, he/she examines different parts of our body. Doctors examine the throat, the lungs, the ears etc. It is only after interconnecting the different results of the examination that they can decide on the illness and on the right treatment*. In the same way, scientists need to establish the connections between the different parts of knowledge in order to derive the right conclusions from their experiments. In other words, they need to explain how the new piece of knowledge (derived from their own experiments) relates to existing knowledge. Interrelatedness of knowledge will help them better understand and explain the different phenomena they examine.

As a result, everything in science is interrelated. *Consider for instance, school breaks and fights among children. Christina, for instance, tells children in her class to stop being* *friends with Maria. Over break time Maria curses Christina. Christina complains that Maria curses her and tells her teacher. The teacher in turn, needs to find out the whole story in order to decide who is to blame for this situation and end up with the right conclusions. The teacher needs to realize that Maria cursed Christina only after Christina asked the whole class to stop being friends with her*. Every new piece of knowledge connects or relates to everything that we knew for the particular topic or other topics until that point in time.

ΠΟΙΟΣ ΕΙΝΑΙ Ο ΡΟΛΟΣ ΤΩΝ ΙΔΕΩΝ ΤΟΥ ΕΠΙΣΤΗΜΟΝΑ ΣΤΗΝ ΕΡΕΥΝΑ;

Οι επιστήμονες ενημερώνονται για τις γνώσεις που ήδη υπάρχουν για ένα φαινόμενο πριν σχεδιάσουν και κάνουν ένα δικό τους πείραμα ή μια παρατήρηση. Όμως για να σχεδιάσουν σωστά το δικό τους πείραμα, θα πρέπει να σκεφτούν τι σημαίνουν οι γνώσεις που ήδη υπάρχουν και αν εξηγούν καλά το φαινόμενο ή όχι. Θα πρέπει ακόμα να σκεφτούν με ποιες άλλες γνώσεις συνδέονται οι γνώσεις που υπάρχουν για το συγκεκριμένο φαινόμενο. Θα πρέπει δηλαδή να καταλαβαίνουν καλά ποια είναι η γνώση που υπάρχει για το θέμα που θέλουν να μελετήσουν.

Πώς θα ήταν να παίζεις ένα καινούργιο παιχνίδι χωρίς να καταλαβαίνεις καλά τους κανόνες του; Οι φίλοι σου μπορεί να σου εξηγήσουν με ποιο τρόπο παίζεται το παιχνίδι. Όμως, για να τα πας καλά στο παιχνίδι είναι πολύ σημαντικό να καταλαβαίνεις και εσύ ο ίδιος πολύ καλά τους κανόνες.

Ένας καλός επιστήμονας όμως, δε φτάνει να ξέρει καλά τις γνώσεις που έχουν ανακαλύψει οι υπόλοιποι επιστήμονες. Θα πρέπει να έχει νέες ιδέες και να σχεδιάζει τα δικά του πειράματα ή έρευνες για να ελέγξει αν οι ιδέες του ισχύουν. Έτσι λοιπόν, κάθε έρευνα στην επιστήμη στηρίζεται σε προηγούμενες γνώσεις. Η έρευνα στηρίζεται όμως και στον τρόπο με το οποίο σκέφτονται οι επιστήμονες για αυτές τις γνώσεις. Δηλαδή, στις ιδέες που έχουν οι επιστήμονες!

Τα αποτελέσματα των πειραμάτων δεν είναι από μόνα τους γνώση. Όταν οι επιστήμονες ολοκληρώσουν ένα πείραμα ή μια παρατήρηση θα πρέπει να σκεφτούν τι σημαίνουν τα αποτελέσματά τους. Με αυτό τον τρόπο θα βγάλουν συμπεράσματα από τα αποτελέσματά τους και θα εξηγήσουν με ποιο τρόπο οι ιδέες τους, που οδήγησαν στο πείραμα, εξηγούν το φαινόμενο που μελέτησαν. Για να βγάλουν τα σωστά συμπεράσματα χρειάζεται ακόμα να σκεφτούν και με ποιες άλλες προηγούμενες γνώσεις συνδέονται αυτά που ανακάλυψαν. Η επιστημονική γνώση, λοιπόν, είναι η ερμηνεία των αποτελεσμάτων. Με άλλα λόγια ο τρόπος που οι επιστήμονες σκέφτονται και εξηγούν τα αποτελέσματα του πειράματος και βγάζουν τα συμπεράσματά τους.

Οι επιστήμονες δεν ανακαλύπτουν απλώς τι υπάρχει και τι συμβαίνει στη φύση. Είναι σημαντικό να γνωρίζουμε ότι κάθε επιστήμονας εξηγεί τα αποτελέσματα πειραμάτων και ερευνών και βγάζει συμπεράσματα ανάλογα με τις δικές του ιδέες και θεωρίες. Σκέψου την περίπτωση της ανάγνωσης βιβλίων. Δύο φίλοι διαβάζουν το ίδιο βιβλίο. Ο ένας μπορεί να βγάλει συμπέρασμα πως το βιβλίο έχει στόχο να κάνει τους αναγνώστες να ευαισθητοποιηθούν για την προστασία του περιβάλλοντος. Ο άλλος μπορεί να βγάλει συμπέρασμα πως το βιβλίο μιλά για την αξία της φιλίας και της ομαδικής δουλειάς. Εάν ρωτήσουμε το συγγραφέα του βιβλίου μπορεί και αυτός να πει διαφορετικά πράγματα. Βλέπουμε λοιπόν πως ο καθένας βγάζει τα δικά του συμπεράσματα σύμφωνα με τις γνώσεις και τον τρόπο σκέψης του.

WHAT IS THE ROLE OF SCIENTISTS' IDEAS IN SCIENCE?

Before scientists conduct an experiment they get informed about existing knowledge. In order to design their own experiment in the right way, they need to think well what existing knowledge tells us and whether it explains the phenomenon well. They also need to think to what other knowledge about the particular topic existing knowledge connects to. In other words, scientists need to understand well existing knowledge about the topic they would like to study.

Consider playing a game without understanding its rules well. Your friends may explain to you how to play the game. To play the game well however, it is important that you also know the rules very well.

It is not enough for good scientists however, to merely know the knowledge discovered by other scientists. Good scientists need to think of new ideas and design their own experiments or research in order to examine the validity of their ideas. Research in science builds therefore from previous knowledge. It is noteworthy however, that research also depends a lot on the way scientists think about knowledge. In other words, research depends on scientists' ideas!

A research result cannot be considered knowledge in and of itself. When scientists complete an experiment or a scientific observation they need to think what is the meaning of their results. This way they will derive conclusions from their results and they will explain how their ideas that originated the experiment in the first place explain the particular phenomenon they studied. Scientific knowledge is therefore the interpretation of the results. In other words, it is the way scientists think and explain experimental results and derive conclusions.

Moreover, scientists do not just discover natural phenomena and how they occur. It is important to realize that every scientist explains the results of research and experiments and derives conclusions on the basis of his/her ideas and theories. *Think about reading. Consider an example where two friends read the same book. One of the two friends may conclude that the goal of the book is to encourage readers protect the environment. The other friend may conclude that the books talks about the value of friendship and group work. If we ask the writer of the book he/she may tell us different things about the meaning of the book. We can* *therefore see that everyone of us derives conclusions according to our knowledge and way of thinking.*

ΠΟΙΟΣ ΕΙΝΑΙ Ο ΡΟΛΟΣ ΤΟΥ ΠΕΙΡΑΜΑΤΟΣ ΚΑΙ ΤΗΣ ΕΡΕΥΝΑΣ ΣΤΗΝ ΕΠΙΣΤΗΜΗ;

Οι επιστήμονες δεν μπορούν απλά να σκεφτούν μια έξυπνη ιδέα ή μια καινούργια θεωρία και να την παρουσιάσουν ως νέα γνώση στην επιστήμη. Σκέψου στην τάξη ότι ένα παιδί έχει μια ιδέα που το βοηθά να λύσει ένα πρόβλημα μαθηματικών με διαφορετικό τρόπο από εκείνο που έδειξε η δασκάλα. Το παιδί αυτό δε φτάνει απλά να πει ότι ανακάλυψε ένα νέο τρόπο να λύσει το πρόβλημα. Θα πρέπει να δείξει με ποιο τρόπο έφτασε στην απάντηση. Έτσι θα πρέπει λοιπόν να δικαιολογήσει την επιλογή του να λύσει το πρόβλημα με αυτό το νέο και διαφορετικό τρόπο. Αλλιώς, ούτε η δασκάλα του θα τον πιστέψει ούτε οι συμμαθητές του.

Οι επιστήμονες λοιπόν όταν σκεφτούν μια νέα ιδέα ή θεωρία θα πρέπει πρώτα να ψάξουν και να βρουν τι γνωρίζουν οι υπόλοιποι επιστήμονες για το συγκεκριμένο θέμα. Θα πρέπει να βρουν τι πειράματα και τι έρευνες έχουν γίνει. Στη συνέχεια θα σχεδιάσουν τα δικά τους πειράματα με σκοπό να βρουν αν η αρχική τους ιδέα είναι σωστή. Θα ελέγξουν δηλαδή αν η ιδέα τους μπορεί να εξηγήσει το φαινόμενο που μελετούν.

Έτσι λοιπόν θα κάνουν πολλές παρατηρήσεις και πειράματα και θα εξετάζουν κάθε φορά αν τα αποτελέσματα που έχουν σε αυτές τις έρευνες συμφωνούν με την αρχική τους ιδέα. Μέσα από αυτή τη διαδικασία (που μπορεί να πάρει χρόνια), οι επιστήμονες καταφέρνουν να αποδείξουν τις αρχικές τους ιδέες ως σωστές. Αυτό σημαίνει ότι καταλήγουν σε μια θεωρία που μπορεί να εξηγήσει ικανοποιητικά κάποιο φαινόμενο.

Όμως, κάποιες φορές συμβαίνει τα αποτελέσματα ενός πειράματος να μην είναι εκείνα που περίμεναν οι επιστήμονες. Αυτό μπορεί να συμβεί όσο προσεκτικά και να κάνουν το πείραμα όσες φορές και να το επαναλάβουν. Τότε θα πρέπει οι επιστήμονες να αλλάξουν ή να διορθώσουν τις θεωρίες τους για να συμφωνούν περισσότερο με τα ερευνητικά αποτελέσματα.

Τα συμπεράσματα που θα βγάλουν οι επιστήμονες από τα αποτελέσματα του πειράματος θα τους βοηθήσουν να εξηγήσουν το φυσικό φαινόμενο που μελετούν. Αυτό δε σημαίνει ότι ανακαλύπτουν την απόλυτη αλήθεια για το φαινόμενο αυτό. Απλά δείχνει ότι η δική τους θεωρία εξηγεί το φυσικό φαινόμενο καλύτερα από άλλες θεωρίες. Στο μέλλον μπορεί να παρουσιαστεί μια άλλη θεωρία που να το εξηγεί ακόμα καλύτερα.

Σκεφτείτε για παράδειγμα την αστυνομία, που πολλές φορές όταν ψάχνει τον ένοχο για ένα έγκλημα μπορεί να θεωρεί ότι ένα συγκεκριμένο πρόσωπο είναι ύποπτο. Μετά από πολλές έρευνες, αποτυπώματα, μαρτυρίες και ένα σωρό στοιχεία μπορεί να αποδείξει ότι πράγματι ο ύποπτος είναι και ο ένοχος που ψάχνει. Μπορεί πάλι ίσως να φανεί ότι ο αρχικός ύποπτος είναι αθώος και ότι άλλος είναι ο ένοχος.

Μια παρατήρηση ή μόνο ένα πείραμα που να δείχνει μια ιδέα σωστή δεν είναι αρκετό. Για παράδειγμα, ένας ασθενής πάει στο γιατρό με πόνο στο στομάχι και οι πρώτες εξετάσεις του γιατρού δείχνουν ότι ο ασθενής έχει πάθει γαστρεντερίτιδα και δίνει τα κατάλληλα φάρμακα. Οι μέρες περνούν αλλά ο ασθενής δε γίνεται καλύτερα και έτσι περνά από περισσότερες και λεπτομερείς εξετάσεις. Μετά από αρκετές εξετάσεις λοιπόν μπορεί να βγει ένα διαφορετικό συμπέρασμα, δηλαδή, ότι ο ασθενής είναι αλλεργικός στο γάλα και ότι θα πρέπει να σταματήσει να το καταναλώνει.

Οι επιστήμονες, λοιπόν, σκέφτονται ιδέες και θεωρίες τις οποίες θα πρέπει να στηρίζουν στα αποτελέσματα της δικής τους έρευνας και της έρευνας άλλων επιστημόνων. Χρειάζεται να δείχνουν ότι οι απόψεις και οι ιδέες τους είναι σωστές μέσα από πολλά πειράματα και έρευνες. Όταν λοιπόν έχουμε μια σειρά ερευνών που τα αποτελέσματά τους συμφωνούν με μια συγκεκριμένη ιδέα ή θεωρία, τότε μόνο μπορούμε να πούμε ότι έχουμε νέα γνώση στην επιστήμη.

WHAT IS THE ROLE OF EXPERIMENTS AND RESEARCH IN SCIENCE?

Scientists cannot just think of a smart idea or a new theory and present it as knowledge in science. *Consider an example of students who have a new idea that helps them solve a math problem in a different way from that presented by the teacher. These students need not only say that they discovered a new way to solve the problem. They need to show how they ended up with the solution. They need to justify their choice to solve the problem with this new and different way. Otherwise neither their teacher nor their classmates will believe them.*

When scientists think of a new idea or theory they need to search and find what other scientists know about the particular topic. They need to find what experiments and what research projects have been completed on the topic. They will subsequently design their own experiments in order to find out whether their new idea is correct. In other words they will examine whether their idea may explain the phenomenon they study.

Scientists will therefore do a lot of observations and conduct experiments and they will examine whether the results of their research support the idea they had in the first place. Through this procedure (that may take years) scientists prove the validity of their ideas. This means that they end up with a theory that can sufficiently explain a phenomenon.

Sometimes however, the results of an experiment are not the expected. This may happen no matter how carefully scientists conduct the experiment or how many times they repeat it. If this happens, then they will have to change or correct their theories in order to agree more with the research results.

Scientists' conclusions from the research results will help them explain the phenomenon they study. This does not mean that they discover the absolute truth about what they study. It simply manifests that their theory explains the particular phenomenon in nature more sufficiently than other theories. One other theory that may explain it even better may be presented in the future.

Consider for instance an example when police investigates a crime and considers a particular person as the main suspect. After numerous investigations, collection of fingertips and testimonies as well as other evidence police may prove that the main suspect is indeed the person who committed the crime. It could even be proved that the original suspect could be innocent and that another person is the criminal.

Only one observation or one experiment supporting the validity of an idea is not enough. *When a patient visits the doctor with a stomachache, the doctor may examine the patient and after diagnosing gastroenteritis he/she may suggest a particular treatment. The patient does not get better in the following days and thus the doctor recommends that the patient was through more extensive and detailed examinations. On completion of the detailed examinations a different conclusion may be reached, that for instance the patient is allergic to milk and that he/she should stop consuming it.*

Scientists think of ideas and theories that they need to support with results from their own research and the research conducted by other scientists. They need to show that their views and ideas are correct through many experiments and research projects. It is only when the results of a series of research projects support a particular idea or theory that we may claim that we have new knowledge in science.