University of Cyprus

DEPARTMENT OF EDUCATION

PROMOTING STUDENT UNDERSTANDING OF THE INTERACTION BETWEEN SCIENCE AND TECHNOLOGY

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A Dissertation Submitted to the University of Cyprus in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

May 2018

VALIDATION PAGE

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Doctoral Thesis Title: Promoting Student Understanding of the Interaction between Science and Technology

The present Doctoral Dissertation was submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy at the ***Department of Education*** *and was approved on the ………. [date of approval] by the members of the* ***Examination Committee****.*

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The present doctoral dissertation was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy of the University of Cyprus. It is a product of original work of my own, unless otherwise mentioned through references, notes, or any other statements.

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ΠΕΡΙΛΗΨΗ

Η προώθηση της φύσης της επιστήμης (ΦτΕ) στη πρωτοβάθμια και δευτεροβάθμια εκπαίδευση αποτελεί ευρέως αναγνωρισμένο στόχο της μάθησης των Φυσικών Επιστημών, αλλά υποβαθμισμένο συγκριτικά με άλλους στόχους, όπως η εννοιολογική κατανόηση, η καλλιέργεια δεξιοτήτων, κ.ά. Η διατριβή ανταποκρίθηκε σε αυτό το πρόβλημα αποσκοπώντας να διευκρινίσει παραμέτρους σχετικές με τη διδασκαλία-μάθηση της ΦτΕ, όπως ο ρόλος της φιλοσοφίας της επιστήμης στο σχεδιασμό Διδακτικών-Μαθησιακών Ακολουθιών (ΔΜΑ), καθώς και η συνεισφορά της Ρητής Επιστημολογικής Διαλεκτικής (ΡΕΔ) στην βελτίωση της κατανόησης των μαθητών για τη ΦτΕ, αλλά και να αναπτύξει αντίστοιχες αποτελεσματικές διδακτικές καινοτομίες. Η επίτευξη του σκοπού της διατριβής εστιάστηκε σε συγκεκριμένη πτυχή της ΦτΕ, η οποία τυγχάνει ανεπαρκούς διερεύνησης και αφορά στο ρόλο της Επιστήμης και της Τεχνολογίας (Ε+Τ) στην κοινωνία. Η προώθηση κατανόησης για το πώς Ε+Τ διαφέρουν και πώς σχετίζονται συνεισφέρει στην κοινωνική προτεραιότητα για εκπαίδευση των μελλοντικών πολιτών στο να αξιοποιούν ερευνητικά αποτελέσματα με τον καλύτερο δυνατό τρόπο για την προώθηση καινοτομίας και επιχειρηματικότητας. Η διατριβή υλοποιήθηκε μέσα από *τέσσερις ανεξάρτητες ερευνητικές εργασίες*. Η *πρώτη* ανέπτυξε το σκεπτικό μιας καινοτόμου διδακτικής επινόησης για διδασκαλία της διασύνδεσης Ε+Τ και το περίγραμμα αντίστοιχης ακολουθίας δραστηριοτήτων που εφαρμόζει το σκεπτικό. Η προσπάθεια βασίστηκε σε τρεις πηγές: την ιστορία και φιλοσοφία Ε+Τ, την υφιστάμενη γνώση για το πώς διδάσκεται η ΦτΕ, τις αρχικές ιδέες μαθητών και δυσκολίες που αντιμετωπίζουν για τη διάκριση Ε+Τ. Η *δεύτερη* και η *τρίτη* εφάρμοσαν το σκεπτικό της πρώτης εργασίας σχεδιάζοντας και αξιολογώντας ΔΜΑ μέσα από διδακτικές εφαρμογές σε μαθησιακά περιβάλλοντα πρωτοβάθμιας και δευτεροβάθμιας εκπαίδευσης, αντίστοιχα. Οι δύο αυτές εργασίες αξιολόγησαν την αποτελεσματικότητα της ΡΕΔ στην κατανόηση των μαθητών για τη διάκριση ανάμεσα στους κεντρικούς στόχους Ε+Τ μέσα από γραπτά έργα αξιολόγησης και συνεντεύξεις που διενεργήθηκαν στην αρχή και στο τέλος κάθε εφαρμογής. Τα αποτελέσματα καταδεικνύουν βελτίωση στην κατανόηση των μαθητών και υποστηρίζουν εμπειρικά το επιχείρημα ότι η κατανόηση των μαθητών για πτυχές της ΦτΕ προωθείται πιο αποτελεσματικά όταν οι ΔΜΑ ενσωματώνουν ΡΕΔ. Τα ενθαρρυντικά αποτελέσματα, αν και περιορίζονται μόνο σε ένα από τους διδακτικούς στόχους των ΔΜΑ ο οποίος θεωρείται προαπαιτούμενος για τους υπόλοιπους, ανατροφοδότησαν την αναθεώρηση των ΔΜΑ ώστε σε μελλοντικές εφαρμογές

να προωθούν πιο αποτελεσματικά το συγκεκριμένο διδακτικό στόχο και να υποστηρίζουν καλύτερα τους μαθητές στην υπέρβαση των δυσκολιών τους. Επίσης, τα αποτελέσματα καθιστούν αναγκαία την ανάπτυξη ερευνητικά επικυρωμένων έργων αξιολόγησης για τους υπόλοιπους διδακτικούς στόχους. Η *τέταρτη εργασία* αντιπαρέβαλε πέντε φιλοσοφικές προοπτικές της σχέσης Ε+Τ, διατύπωσε αντίστοιχες συνέπειες από τη χωριστή εφαρμογή κάθε προοπτικής για το σχεδιασμό ΔΜΑ στη μάθηση των φυσικών επιστημών και συμπέρανε ότι μονόπλευρη υιοθέτηση κάθε προοπτικής κατά το σχεδιασμό ΔΜΑ οδηγεί σε παρανοήσεις στην κατανόηση των μαθητών. Αυτό το συμπέρασμα οδήγησε στην εισήγηση μιας συναινετικής προσέγγισης κατά το σχεδιασμό ΔΜΑ για την εξοικείωση των μαθητών με τη διασύνδεση Ε+Τ ή ακόμη και άλλων πτυχών της ΦτΕ, σύμφωνα με την οποία ο σχεδιασμός ΔΜΑ για εισαγωγή φιλοσοφικών πτυχών της επιστήμης οφείλει να δομείται σε φιλοσοφικά ενημερωμένες αποφάσεις, αλλά ταυτόχρονα να υπερβαίνει μεμονωμένες φιλοσοφικές προοπτικές και να βοηθά τους μαθητές να κατανοούν θεμελιώδεις ιδέες που εξαιρούνται από τις πολυπλοκότητες του φιλοσοφικού υποβάθρου.

ABSTRACT

Helping elementary and secondary school students understand aspects of the Nature of Science (NOS) is a widely recognized goal of science education that is underestimated comparatively to other goals, such as conceptual understanding, scientific skills, etc. I responded to this problem by intending to elucidate parameters related to NOS teaching-learning, such as the role of philosophy of science in the design of teaching-learning sequences (TLS), as well as the role of explicit epistemological discourse (EED) for improving students' awareness about the NOS and simultaneously develop corresponding illustrations of effective teaching innovations. I pursued this purpose through *four distinct studies* that focused on a NOS aspect, which lacked adequate investigation thus far, the role of Science and Technology (S&T) in society. Promoting student understanding of how S&T differ and how they relate has a great potential in contributing to the societal priority of training future citizens in making optimum use of research results in innovation and entrepreneurship. The *first study* developed the rationale underlying a novel teaching proposal and an outline of the corresponding activity sequence that embodied this rationale for teaching innovations about the interrelationship between S&T. The effort relied on inputs from three sources: the history and philosophy of S&T, existing knowledge on NOS teaching-learning, empirical data on students' initial ideas and the difficulties encountered while learning about this topic. The *second and third studies* designed TLSs that applied this rationale and evaluated them through teaching interventions. Both studies assessed the effectiveness of EED for raising students' awareness of the distinction between the different overarching goals of S&T (producing reliable knowledge about natural phenomena vs developing solutions to respond to human problems and needs) through pre-post tests and interviews. The results demonstrated improvement in young learners' ability to improve their understanding and provided empirical evidence regarding the argument that students' awareness of NOS was more effectively promoted when integrating EED in science teaching-learning. The promising results, although concentrated to one of the learning objectives that was a prerequisite for exploring connections between S&T, provided feedback for the revision of the TLSs to further enhance their effectiveness by further scaffolding students overcome their difficulties and better achieve the learning objectives in future implementations. Also, the results necessitated the need to consider for enhancing the development of more validated instruments for the remaining learning objectives. The *fourth study* compared five perspectives of the relationship between S&T reported in philosophy, reflected on corresponding implications from separate applications of these perspectives for

the design of TLSs in S&T education and concluded that exclusive adoptions of any of these five approaches when designing TLSs reported flaws and lacked validity in students' awareness. This conclusion led to suggesting the coherence approach when designing TLSs for familiarizing students with the relationship between S&T or any other NOS aspect, according to which, the design of TLSs for introducing philosophical aspects of science should be structured on philosophically informed decisions but simultaneously transgress individual philosophical perspectives and help students develop fundamental ideas while excluding the intricacies of the underlying philosophical dialogue.

ACKNOWLEDGEMENTS

Work presented in this dissertation has been partially supported by the European Union through the European Communities Research Directorate General in the project Materials Science (University-school partnerships for the design and implementation of research-based ICT-enhanced modules on Material Properties, Science and Society Programme, FP6, SAS6-CT - 2006-042942). Therefore, I thank my supervisor Dr Constantinos P. Constantinou for providing me with the opportunity to connect my studies to a European Research Project, for responsibly supporting me in every step and mainly for inspiring me to respond to various academic challenges during my studies with patience, persistence and apprenticeship attitude. I benefited greatly from the mentoring of Dr Constantinou and I deeply thank him for this.

Additionally, I thank the rest of the members of the Examination Committee whose critical comments and suggestions benefited in finalizing the dissertation. I specially thank Dr Demetris Portides for his willingness to discuss and guide me in certain critical instances during the progress of my studies.

I also want to thank members of the Learning in Science Group of the University of Cyprus, for their help during the data collection process. I express special thanks to my critical friend Dr Nicos Papadouris because our previous collaboration during my master's studies inspired me to further continue my studies. I am grateful for his unconditional interest to take the time to understand the context of my doctoral studies and discuss my reflections throughout the progress of the dissertation, as well as for providing his feedback on individual chapters of it.

Additionally, I would like to thank all the principals and teachers who allowed me access to their classroom and devoted their time to this study, as well as all the student participants for their collaboration.

Finally, I would never have made it this far without my family. This dissertation would not have been possible without the love, support and encouragement I received from my parents, brothers and sisters and special friends. I express my gratitude to all of them. Finally, I express my gratitude to a special member of my family and my friends, my truelove husband, whose persistent support pushed me through the final stage of this journey.

DEDICATION

This work is dedicated to my husband, Andreas, who has been a constant source of support and encouragement during various challenges of writing the doctoral thesis and for promising me a trip to Venice when I finish it. This work is also dedicated to my parents, Flourentzos and Noulla, who always love me unconditionally and whose good examples taught me to work persistently for the things that I aspire to achieve.

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CHAPTER I: INTRODUCTION

1. The need for this dissertation

The Nature of Science (NOS) is acknowledged as a core learning objective of science education and an important component of scientific literacy (AAAS, 1989; Abd-El-Khalick, 2013; Driver et al., 1996; Kang et al., 2005; Lederman, 2007; McComas & Olson, 1998; NRC, 1996, 2000, 2007, 2012; Taber, 2008 among many others). However, conventional science teaching does not pay equivalent attention to the NOS as it does with the remaining science learning objectives such as conceptual understanding or scientific skills as compared to this acknowledgement. Hence, more research is needed to elucidate various parameters that become relevant to teaching and learning about the NOS, and there is a need to develop corresponding illustrations of effective teaching innovations (Abd-El-Khalick, 2012; Lederman, 2007; Lederman & Lederman, 2014; Sandoval & Morrison, 2003), especially in the lower school grades (Akerson & Volrich 2006; Kang et al., 2005). One of these parameters concerns the role of Explicit Epistemological Discourse (EED) for improving students' awareness about NOS, while another concerns the role of the philosophy of science in the design of Teaching-Learning Sequences (TLSs).

This dissertation aimed to contribute to investigating this potential by focusing on an aspect of the NOS which had not been adequately studied thus far. Specifically, the dissertation problematized the role of Science and Technology (S&T) in society, their interrelationship and sought to investigate student understanding of this role and ways to enhance it. Connections between S&T are of contemporary interest because of the need to make better use of the results of research in innovation and entrepreneurship. Science education can contribute to this societal priority by promoting student understanding of how S&T differ and how they relate (Jones & Buntting, 2015; McComas, 2008; Osborne et al., 2003).

S&T are two highly interacting fields of social activity. Nevertheless, it is possible to consider them as distinct domains. A fundamental difference between S&T relates to the difference in the orientation, i.e., between the overarching goals that the two field pursue: Science is the enterprise that seeks to generate reliable knowledge; technology is the enterprise that seeks to respond to human needs by developing solutions to problems (AAAS, 1989; Agassi, 1980; Arageorgis & Baltas, 1989; Bybee, 2011; Custer, 1995; Constantinou, Hadjilouca & Papadouris, 2010; Gardner, 1993, 1994; ITEA, 2007; Jones, 2006; NRC, 1996). From a methodological viewpoint, another difference between S&T

concerns the core processes adopted for achieving the different goals of S&T. Specifically, controlled experimentation or, more broadly, investigation is a core process in science, while design is a core process in technology (de Vries, 2009; Jones & Buntting, 2015; Lewis, 2006; NRC, 1996, 2012; Constantinou et al., 2010). Given the complex nature of both enterprises (S&T), their interconnections and mutual influences are predictably elaborate. Therefore, developing awareness about the interaction between S&T posits an interesting challenge both for science education and technology education.

2. Research questions

Specifically, the dissertation addressed the following research questions:

1. How can the historical evolution of the relationship between S&T contribute to curriculum design and development processes? (Study 1 in Chapter II)
2. To what extent can upper-elementary school students improve their understanding about the different overarching goals of S&T through a specially designed TLS that combines inquiry-oriented and design-based activities integrated with explicit NOS/NOT discourse? (Study 2 in Chapter III)
3. What difficulties do upper-elementary school students encounter in their attempts to develop an understanding of the difference between the overarching goals of S&T? (Study 2 in Chapter III)
4. To what extent does extensive interaction with inquiry-based and design-based activities (non-EED condition) improve upper-secondary school students' awareness about the difference between the overarching goals of S&T? (Study 3 in Chapter IV)
5. To what extent does the integration of EED activities (EED condition) in a TLS that combines inquiry-based and design-based activities improve upper-secondary school students' awareness about the difference between the overarching goals of S&T? (Study 3 in Chapter IV)
6. What is the educational value of coherence in efforts to integrate issues stemming from the philosophy of science in science teaching and learning? (Study 4 in Chapter V)

3. The constituent studies

The dissertation was completed through four distinct studies that investigated the stated research questions. The *first study* developed the rationale for a teaching innovation about the interrelationship between S&T. The effort relied on inputs from three sources: the history and philosophy of S&T, existing knowledge on the teaching and learning of the NOS, as well as empirical data on students' initial ideas and the difficulties they encounter while learning about this topic. The end product of this first study was a detailed description of the rationale underlying a novel teaching proposal and an outline of the corresponding activity sequence that it embodied.

The *second and third studies* applied the rationale developed in the first study in evaluations of teaching interventions. Both studies evaluated the effectiveness of EED for raising students' awareness about NOS by exploring whether the combination of inquiry-oriented and design-oriented teaching and learning could provide a rich context for raising awareness about the interrelationship between S&T. Specifically, the second study concerned upper-elementary school students' interaction with a specially designed TLS. The third study integrated epistemologically oriented learning objectives and corresponding activities regarding the interrelationship between S&T in an existing TLS and was designed to address the needs of upper-secondary school students. The end products of these studies were manuscripts describing the research process and what was learnt about designing TLSs on this topic, accompanied by suggestions on improvements and refinements to the learning materials.

More specifically, the *second study* reported on a process of technological design situated in a design-based research paradigm that implemented a specially designed TLS with a class of upper-elementary school students. The effectiveness of the TLS was assessed with measurements of students' understanding prior to and after the teaching intervention through their responses to written tasks and follow-up semi-structured interviews. The analysis of the collected data explored students' potential progress because of the implementation of the designed TLS. The results demonstrated the possibilities in young learners' ability to develop NOS understandings in the topic under emphasis and provided feedback for the revision of the TLS so as to further enhance its effectiveness with respect to better achieving the stated learning objectives in future implementations.

The *third study* applied a combined pre-post test and interview design to evaluate upper-secondary school students' awareness of the interrelationship between S&T as part of two teaching interventions with two versions of a TLS on electromagnetic properties of materials. The targeted difference between the two interventions was the integration of EED activities regarding the interrelationship (i.e., differences and connections) between S&T in the second version of the TLS. The outcomes of the study provided empirical evidence regarding the argument that students' awareness of NOS was more effectively promoted when integrating EED in science teaching and learning.

The *fourth study* focused on the role of philosophy in the design of TLSs. Specifically, teaching and learning about the relationship between S&T was used as an example to support the claim that any educational reform should transgress individual philosophical approaches or perspectives, and, also, should be structured on philosophically informed decisions.

The next four chapters elaborate each of these four studies, correspondingly. Each chapter is structured as an independent study with separate abstract, introduction, literature review, methodology, results and discussion sections. The last chapter summarizes the four studies, synthesizes the various issues raised in the individual discussion sections and reflects on implications drawn from these discussions. Additionally, this sixth chapter discusses contributions of the dissertation and recommends directions for future research.

CHAPTER II

Developing the rationale for a teaching innovation about the interrelationship between science and technology

Abstract

This study refers to the development of a teaching innovation for the NOS, for students aged 11-15, which specifically focuses on the interrelationship between S&T. The development of the teaching and learning materials relied on inputs from three sources: the history and philosophy of S&T, existing knowledge concerning the teaching and learning about the NOS, empirical data on students' initial ideas and difficulties about this topic. The first served to provide an account for the various forms of interaction between S&T, which, in turn, guided the formulation of epistemologically coherent learning objectives. The second provided the pedagogical grounds on which to base the design of the activities. The third facilitated the design of activities that build on students' productive initial ideas, while providing them with guidance to resolve the difficulties they tend to encounter. In this study, we describe the rationale underlying the teaching and learning materials and we describe the activity sequence they embody.

Keywords

Teaching/learning about the nature of science; curriculum design

1. Introduction

Understanding about the NOS, i.e., how scientific knowledge is generated, organized and justified, is widely recognized as a core learning objective of science education[1]. However, despite the acknowledgement of its importance, it is not typically addressed by conventional science teaching in an explicit manner. In this light, it would make sense to anyone that there is a need for more research so as to better understand the various parameters that become relevant on teaching and learning about the NOS and also there is a need to develop teaching innovations in this endeavor.

This study is part of a research project that sets out to contribute towards addressing this latter need for a specific NOS aspect. In particular, it seeks to develop and validate teaching and learning materials to help students, aged 11 to 15, develop awareness with respect to the role of S&T in society and to appreciate their interrelationship.

Recent suggestions concerning educational treatments of the relationship between S&T scrutinize the notion of technoscience as an educational approach that equally combines technology and science education (Bencze, 2001; Tala, 2009). This notion addresses the current imbalance between the respective status given to technology education and science education (technology receives lower appreciation) (Bencze, 2001; Layton, 1993). It emerges through the prism of recent philosophical and historical analysis of scientific activity (especially physics) and has revealed that technology, beyond being part of physics from a methodological viewpoint "through providing both scaffoldings and limits of physical reality accessible to us", it is also seen as part of physics from an epistemological and cognitive viewpoint since it "affects our conception of reality" (Tala, 2009, p.282). Because of these fundamental roles, it is supported that "technology should be an organic part of physics education" (Tala, 2009, p.282). Within the technoscience notion, natural reality is shaped by embodying the interaction between S&T, where technology underpins modern scientific process and vice-versa (Tala, 2009).

S&T have come to be in continuous interaction. An indication of this pairing is the emergence of interdisciplinary research fields (Porter & Rafols, 2009) such as climate change, genetic mechanics and materials science. On the one hand, scientists strive to reach, through abstraction, generalizable coherent explanations and predictions of various phenomena (e.g., climate change science aims to formulate theories that explain and predict climate change phenomena). On the other hand, technologists, instead of generalizing, aim

[1] On this see AAAS (1993), Driver, Leach, Millar, and Scot (1996), Flick and Lederman (2006), Kang, Scharmann, and Noh (2005), Lederman (1992), McComas (2002), NRC (1996).

at developing solutions for specific problems (e.g., photovoltaic systems technology research seeks to optimize various material properties that serve towards increasing the efficiency of photovoltaic systems).

Both these elements (scientific understanding and technological innovation) are necessary components of many interdisciplinary fields. Taking climate change research as an example, it seeks to advance our understandings of the various agents that drive complex phenomena, including global warming, polar ice melting, desertification and flooding. It also seeks to develop scientific models of the interactions between parameters that influence the evolution of these phenomena, such as carbon dioxide concentration in the atmosphere or the intensity of solar radiation at different points on the surface of the earth. At the same time, climate change research requires instrumentation, which is developed through technological design processes, in order to collect the data that are required for refining and validating the models. It also requires technological innovations for developing methods and procedures for constraining human impact on climate change phenomena. All these require that S&T be blended in an effective synergy aiming to address aspects of the overall issue.

The present study departs from the premise that education has an important role to play in preparing students (the citizens of tomorrow) to appreciate the role of S&T in society, since they will be called to engage with them either as researchers or as scientifically literate citizens with an interest in participating in public discourse on setting research and innovation priorities, for instance. We also assume that only someone who has an adequate understanding of what science is and what technology is, can participate in meaningful discourse about their interrelationship with reference to their distinct contributions. In line with this notion, relevant science education research literature recognizes that understanding that S&T are different and simultaneously support each other is one of the aspects of the NOS that could and should be dealt with in school science (McComas, 2008; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

The aim of this study is to elaborate a teaching proposal for developing students' understanding about the interrelationship between S&T. Elaborating the rationale underlying the teaching proposal, we explore the value of a certain type of resource that we have employed, namely the history and philosophy of S&T. Specifically, we have undertaken the task of exploring the historical setting behind the nature of the relationship between S&T with a view to utilize this information in the curriculum development process.

The study is structured in the following way: section 2 gives the background for teaching and learning about NOS issues from the perspective of science education and it specifically focuses on the importance of acquiring epistemologically informed understandings about the interrelationship between S&T and the available empirical evidence about students' initial ideas and difficulties on this issue; section 3 seeks to map the historical background of the relationship between S&T with a view to identify perspectives of this relationship; section 4 describes the structure of teaching and learning materials that we have developed for promoting students' awareness of the interrelationship between S&T.

2. Teaching and learning about the NOS

2.1. Why should the NOS be a component of school science?

The term NOS refers to the ways through which scientific knowledge is constructed, evaluated and validated (Lederman, 2007; McComas, 2002). Helping students develop understanding of the NOS is widely recognized as an important learning objective of science teaching (AAAS, 1989, 1993; NRC, 1996, 2000, 2007). One important reason for this is that appreciating aspects of the NOS constitutes an integral component of public understanding of science, or otherwise scientific literacy, which has been extensively discussed as a pivotal element for the development of sustainable societies (Driver, 1996). The argument underlying this entails four aspects, as summarized below:

> Utilitarian argument: an understanding of the nature of science is necessary if people are to make sense of the science and manage the technological objects and processes they encounter in everyday life (p.16).
>
> Democratic argument: an understanding of the nature of science is necessary if people are to make sense of socioscientific issues and participate in the decision-making process (p.18).
>
> Cultural argument: an understanding of the nature of science is necessary in order to appreciate science as a major element of contemporary culture (p.19).
>
> Moral argument: learning about the nature of science can help develop awareness of the nature of science, and in particular the norms of the scientific community, embodying moral commitments which are of general value (p.19).

Another reason that further highlights the importance of this learning objective is that it could facilitate the development of other components of what constitutes competence in science, such as conceptual understanding, positive attitudes towards science, reasoning skills, and effective engagement with socio-scientific issues as discussed in Driver et al. (1996).

2.1.1. The appropriateness of teaching and learning about the NOS as a learning objective

The appropriateness of promoting students' understanding about the NOS as a learning objective has been questioned in view of the lack of consensus among philosophers of science on how science operates (Alters, 1997). Essentially, this position rests on the premise that it is not reasonable to expect students to become knowledgeable about the NOS given that the philosophers of science do not really agree on how science as an enterprise should be best described. One argument that has been made in the science education literature, in response to this position, is that the disagreements among philosophers are not necessarily relevant to school science, in that science teaching merely aims at helping students formulate a simplified account of how science works. Despite the lack of consensus in the philosophy of science, it would still be possible and useful to help students develop a set of fundamental ideas while excluding the intricacies of the underlying discourse. This perspective is consistent with the consensus that seems to exist within science education on such a set of ideas[2]. For example, these ideas include, amongst others, the durable, albeit tentative, nature of scientific theories, the central role of empirical evidence in science and the distinction between observations and inferences. It is important to note, that the interrelationship between S&T, which is the focus of the present study, is included among this set of ideas (McComas, 2008; Osborne et al., 2003).

2.2. What are the main implications from existing research on teaching and learning about the NOS?

2.2.1. Aspects of the NOS can be productively introduced and elaborated in school science starting from an early stage

Obviously, attaining a full grasp of the various aspects of the NOS requires a systematic and repeated teaching elaboration throughout school science. However, one important finding that has been consistently reported in the research literature is that this elaboration could usefully start from a very early stage. Indeed, the available empirical evidence suggests that it is possible to impact on elementary students and help them acquire informed conceptions about aspects of the NOS[3], through appropriately designed learning environments. This, however, posits the formulation of a series of age-appropriate learning objectives that

[2] On this see Abd-El-Khalick, Bell, and Lederman (1998), Lederman (2007), McComas (2008), Osborne et al. (2003).

[3] On this see Akerson and Donnelly (2010), Akerson and Volrich (2006), Carey, Evans, Honda, Jay, and Unger (1989), Khishfe and Abd-el-Khalick (2002), Khishfe and Lederman (2006).

become increasingly more elaborate and epistemologically coherent (Rudolph, 2000; Taber, 2008).

2.2.2. Engagement in EED as a critical factor for the effectiveness of teaching about the NOS

One of the most well grounded findings that have emerged from the existing research on teaching and learning about the NOS refers to the significance of the systematic engagement of students in explicit epistemological discourse, as an important factor facilitating their understanding of the NOS (Clough, 2006; Lederman, 2007; McComas, 2002). This finding is supported by empirical evidence stemming from two main directions. The first, which is the most direct, is concerned with the significant learning gains that have been reported in studies purporting to teach aspects of the NOS by systematically engaging students in explicit epistemological discourse[4]. The second direction refers to studies illustrating that the exclusion of this theme from explicit teaching is not likely to bring about any improvement in students' appreciation of the NOS. These studies can be further classified in two categories. The first refers to research studies reporting on attempts to pursue learning objectives relevant to explicit aspects about the NOS, though, without treating them in an explicit manner. Underlying such implicit approaches is the assumption that understanding of the NOS could emerge as a by-product of students' engagement in inquiry-based learning environments. However, the results from the assessment of students' learning outcomes fail to corroborate this assumption in that they do not suggest significant learning gains[5]. The second category includes studies that sought to evaluate students' awareness of various NOS aspects. These studies demonstrate that students' awareness does not seem to improve with age or with the sustained exposition to conventional science teaching. Couple this with the fact that conventional science teaching typically fails to explicitly address learning objectives relevant to the NOS, highlight the pivotal role of engaging students in EED (Abd-El-Khalick, 2006; Kang et al., 2005).

In addition to highlighting the importance of engaging students in EED the existing literature has also provided useful insights into possible ways of integrating this in science teaching. Specifically, it suggests three possible approaches, as follows:

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[4] On this see Akerson and Donnelly (2010), Akerson and Volrich (2006), Carey et al. (1989), Khishfe and Abd-El-Khalick (2002), Khishfe & Lederman (2006), Peters (2012).

[5] On this see Abd-El-Khalick & Lederman (2000a), Khishfe and Abd-El-Khalick (2002), Lederman (1992), Moss, Abrams, and Robb (2001), Sandoval (2003, 2005); Sandoval and Morrison, 2003.

(i) Nonintegrated (de-contextualized) activities in which the elaboration of NOS aspects is disconnected from the science content. Examples can be found in Lederman and Abd-El-Khalick (2000) and Bell (2008) among others.

(ii) Integrated (contextualized) activities that seek to embed the elaboration of NOS aspects within the science content (e.g., Khishfe & Lederman, 2006; Walker & Zeidler, 2003; Zeidler, Walker, Ackett, & Simmons, 2002). A variant of this type of activity embeds the epistemological discourse in the context of the elaboration of content.

(iii) The third approach involves engaging students in epistemological discourse while studying episodes drawn from the history of science[6]. Even though this approach does not typically pursue conceptually oriented learning objectives, epistemological discourse is associated with the content of science and it could be therefore conceived as a variant of the integrated approach.

2.3. Teaching and learning about the interrelationship between S&T

2.3.1. Importance

This study aims to contribute towards addressing the need for teaching innovations and specifically focuses on a particular aspect of the NOS, namely the interrelationship between S&T. The selection to focus on this particular topic can be justified for a number for reasons, which have been elaborated elsewhere (Constantinou, Hadjilouca, & Papadouris, 2010). The most important of these can be summarized as follows:

- It is recognized as an important aspect of the NOS (McComas, 2008; Osborne et al., 2003)
- It has not been adequately studied thus far, especially in the case of elementary and middle school students (Akerson & Volrich, 2006; Kang et al., 2005)
- Realising the potentials and constraints of the two fields is of great importance for developing the ability to effectively engage with socio-scientific issues (Sadler, 2004; Zeidler, Sadler, Simmons, & Howes, 2005), which is recognized as an important component of both scientific and technological literacy[7].

[6] For this see examples in Abd-El-Khalick and Lederman (2000b), Kim and Irving (2010), Olson, Clough, Bruxvoort, and Vanderlinden (2005), Rudge and Howe (2009), Solomon, Duveen, Scot, and McCarthy (1992), Straits and Nichols (2007), Yip (2006).

[7] For this see AAAS (1989), ITEA (2000, 2003), Jones (2006), Kolstø (2001, 2008), Sandoval (2005).

- New knowledge in this area could inform and facilitate attempts to devise mechanisms for increasing students' interest towards S&T courses[8] and it could offer them guidance on future careers. More specifically, it could help the education system to encourage students to make more informed decisions and this could, in turn, increase the likelihood for successful career choices.
- The prevalent conceptions about S&T are important for efforts to communicate publicly their role in society and the outcomes of the various policy procedures for developing funding priorities. For instance, the level of public support for an innovation system in close symbiosis but distinct from the science system, and also closely related with financial investment mechanisms, is directly related to the level of public understanding of the differences between S&T and the diverse roles they play in economic development.

2.3.2. Students' initial ideas on the distinction between S&T and relevant difficulties

The available empirical data from existing research indicate that students possess invalid and unarticulated ideas about the distinction and the relation between S&T (De Vries, 2005; Ryan & Aikenhead, 1992), which do not seem to improve as a result of additional exposition to conventional science teaching or maturation (Constantinou et al., 2010a). Specifically, they tend to employ a range of (sometimes mutually exclusive) criteria, in an unsystematic and inconsistent manner, for determining whether certain research goals seem more compatible with science or technology. For instance, depending on whether the focus of a given research goal is placed on either a natural or an artificial phenomenon they are inclined to associate it with science or technology, respectively. Another criterion they tend to activate refers to the processes employed for realizing the given research goal in that they tend to restrict specific processes to either science or technology. For instance, the conduction of experiments is often exclusively attributed to science whereas any kind of construction activity refers to technology.

The available empirical data also highlights specific difficulties that seem to hamper students' understanding of the interrelationship between S&T (Constantinou et al., 2010a). These difficulties seem to fall in three categories. The first includes difficulties that integrate students' conceptions about S&T. One such difficulty relates to students' tendency to view technology as the application scientific knowledge (Constantinou et al., 2010a; De Vries, 2005). The other two categories refer to students' difficulties with respect to the nature of

[8] For this see Gago et al. (2004), NSF (2003), OECD (2006), Roberts (2002).

either science or technology, though they bear a direct relevance to students' attempt to differentiate between these two fields and appreciate their interrelation. One example of such a difficulty with respect to the NOS relates to students' failure to appreciate that understanding the mechanism underlying the operation of natural phenomena constitutes a worthwhile achievement in its own right, even though it might not be associated, in an obvious manner, with useful practical applications (Constantinou et al., 2010a). In a similar manner, a couple of examples pertaining to students' understanding of the nature of technology include their failure to appreciate creativity as an important component of technological design (Constantinou et al., 2010a; De Vries, 2005) and their tendency to restrict technology to end-products excluding important aspects of the processes that led to their production (Constantinou et al., 2010a; DiGironimo, 2010; Rennie & Jarvis, 1995).

3. The interrelationship between S&T: historical setting

The inherently complex issue of the interrelationship between S&T in combination with the fact that this is not typically addressed by conventional science teaching, tends to contribute to the development of epistemologically distorted views about these issues. In this section we seek to reveal the value of the history of S&T as a resource for guiding the development of learning materials, by specifying and elaborating the different perspectives relevant to the relationship between S&T as they emerge from the review of the relevant literature. Specifically, we attempt to illustrate the variety of possible interactions between S&T through indicative examples from the history of S&T.

3.1. The initial independency between S&T

3.1.1. Beginnings of technology: technology functioned independently from science

Technology preceded science and existed independently of any systematic activity in science for thousands of years[9]. Archeological findings amply demonstrate techniques and technological tools invented and used thousands of years ago. It is believed that these constitute the primary form of history (Cardwell, 1994) and it could be argued that technology is as old as the human kind itself. George Bassala in his book "The evolution of technology" mentions that stone industry is one of the most important forms of early technology that flourished for more than two million years. The effective construction of stone knifes and axes became possible because experience taught people that particular

[9] For this see Arageorgis and Baltas (1989), Basalla (1988), Cardwell (1994), Gardner (1997), Gil-Perez et al. (2005).

materials and techniques worked better than others. This reliance on experience was also evident in the case of processing metals (first indications on the use of metals are dated around 6000 B.C.). The procedure for the extraction of the copper or the bronze relied on techniques that were developed and refined on the basis of experience, totally independent of any conceptual understanding of the underlying ideas. Indeed, it was not until the 18th century that simple metallurgic procedures were described in terms of conceptual ideas drawn from chemistry, while even in our days there are procedures of modern production whose chemical base still remains unknown (Basalla, 1988). These examples demonstrate that technology without any input from science, created elaborate structures, devices and domains of activity (Basalla, 1988; Wolpert, 1992). Otherwise we could not explain the monumental architecture of antiquity or Renaissance cathedrals and the mechanical technology (windmills, watermills, clocks) of the Middle Age, nor could we explain the brilliant works of art of ancient Chinese technology. The flourishing of crafts and trade guilds throughout the middle ages and renaissance, somewhat resembles modern forms of organization of professional communities and pays testament to the broad prevalence of technological enterprise in the societies of those times. In contrast, science was a peripheral, fringe activity at the time that served the curiosities of an elite minority of people privileged enough to have access to the resources required to focus on natural philosophy.

It seems that the requirement to satisfy human needs, historically preexisted the need for understanding how nature works. Basalla (1988) discusses the relation between technology and addressing human needs using the known Aesop myth about the thirsty hawk.

> 'Once upon a time, a crow was about to die of thirst came upon a tall pitcher partially filled with water. He tried again and again to drink from it, stooping and straining his neck, but his short beak could not reach the surface of the water. When he failed in an attempt to overturn the heavy vessel, the bird despaired of ever quenching his thirst. Then he had a bright idea. Seeing loose pebbles nearby, the crow began dropping them into the pitcher. As the stones displaced the water, its level rose. Soon the crow was able to drink his fill. The moral: necessity is the mother of invention'. Modern commentators have elaborated in this message by praising those individuals who, when placed in seemingly impossible situations, do not despair but instead use wit and ingenuity to invent new devices and machines that solve the dilemma, meet basic biological needs, and contribute to material progress (Basalla, 1988, p.6).
>
> The belief that necessity spurs on inventive effort is one that has been constantly invoked to account for the greatest part of technological activity. Human have a need for water, so they dig wells, dam rivers and streams, and develop hydraulic technology. They need shelter and defense, so they build houses, forts, cities, and military machines. They need food, so they domesticate plants and animals. They need to move through the environment with ease, so they invent ships, chariots, carts, carriages, bicycles, automobiles, airplanes, and spacecraft. In each of these instances

> humans, like the crow in Aesop's story, use technology to satisfy a pressing and immediate need (Basalla, 1988, p.6).

Beyond basic survival needs, technological innovations are supported or hampered by unspecified, ideological factors that generally define cultural needs. Mumford (1961) highlights that it is impossible to isolate an invention or an inventor from the source or the culture that either provided the opportunity and stimulus, or hampered and rejected any kind of development. Furthermore, Mumford (1961) provides a series of historical icons such as the construction of the Egyptian pyramids, the machinery of Benedictine monks, and the evolution of certain modern artifacts through toys. The construction of Egyptian pyramids was not an outcome of using innovative mechanical apparatus, but a result of the religious faith invested in the Pharaoh, so as to command the "the first complex machine, the thousand-legged human machine, made of specialized, inter-changeable, and replaceable parts, operating from a single control center …" (p.232). The means to do this "did not come from the internal development of technics: just the other way round, it was the magnification and exaltation of human power that came in with the new solar religions, opening up immense vistas in time and space, that made possible the contrivance of an altogether new species of complex machine" (Mumford, 1961, p.233). In this sense, the ancient Egyptians were successful technologists without having any scientific understanding (Singh, 2004).

3.1.2. Beginnings of science: science functioned independently from technology

The development of scientific thought in the circles of ancient Greek philosophy mainly rested on the curiosity and worries of philosophers such as Aristotle, Eratosthenes, and Aristarchus. These philosophers studied the universe, based on logic, mathematics, observation and measurement, laying the foundations of early observational science, well before the idea of experimental falsification came about (Singh, 2004). Prevailing ideas about the universe were advanced by Aristotle around 300 BC. Aristotle postulated that the earth is located at the center of the universe and that matter consisted of four main elements: earth, water, air and fire. Each of these elements had its natural position in the universe and the natural place of different objects was determined based on the concentration of each of the four elements in its composition. For example, if an object mainly consisted of earth (e.g., a stone) was released from a certain height it would fall downwards until it reached its natural place (i.e., the earth). Aristotle's theory was abandoned 2000 years later by Galileo's initiative in experimental science.

Stillman Drake in his book "Galileo" mentions that Aristotle had nothing against practical knowledge which he called art. He just separated it from scientific knowledge which he called science. For Aristotle, the difference between art and science was not the difference between application and theory, but the one between the sources of knowledge and the targets of knowledge. The source of technical knowledge was practical experience and its goal was for someone to know what to do next time. The source of scientific knowledge was logic and the goal was to understand things through their causes (Drake, 1980).

The absence of processes that empirically tested hypotheses (i.e., experiments) is consistent with the absence of connection between S&T in ancient times. A possible explanation for this has to do with the fact that conducting experiments was most times impractical because of the lack of appropriate measurement instruments (e.g., instruments for measuring time in small intervals only became available three centuries ago). Another dimension related to this lack of connection between S&T refers to people's thinking. According to ancient Greek thinking, handwork was not appropriate for free citizens, but for slaves, who belonged in a lower social class. Thus experimentations that clearly involved handwork were not an acceptable form of activity for philosophers. An additional dimension concerning the absence of connection between technology and science relates to the fact that ancient Greeks had developed geometry, a field that deals with abstract concepts such as dimensionless points and straight lines. In this manner, most ancient Greek philosophers achieved results of great generality that could not have been an outcome of measuring real objects. Therefore, in their attempts to generate abstract concepts about the universe they assumed that the real world was not a suitable model (Kuhn, 1996).

3.2. The later dependency between S&T: perspectives of the interaction between the two fields

As noted in the previous section a major perspective of the relation between S&T is their initially independent function. It took many centuries before each of these enterprises could conceive and exploit each other's contributions for its advancement. Even during the scientific revolution there were barriers that acted against the development of any relationship between the two. Beyond the strength of the Aristotelian tradition that prevailed until the beginnings of the 17th century, there were also leftovers of mysticism, which in combination with a rebirth of the skepticism tradition, led to lingering doubts as to whether what we now call knowledge could ever exist. These difficulties were resolved only through the contributions and painstaking efforts of scientists like Galileo, Newton and many others. Even the three inventions that were identified by Francis Bacon "as the source of great changes in Renaissance Europe – printing, gunpowder and the magnetic compass – were imports from China and owed nothing to science" (Wolpert, 1992, p.28). Until the

Renaissance, all major technological achievements (e.g., fermentation, the use of quinine in medical practice) were attained entirely through the activity of craft technologists without any obvious scientific contribution (Arageorgis & Baltas, 1989).

> A craft technology may be roughly characterized as follows: It is based on practical knowledge and empirical observations of factual correlations and it employs techniques and methods (trial and error, analogies etc.) which are justified only by their success in bringing about the desired state of affairs (i.e. solving the corresponding technological problem). There are no well defined criteria determining the circumstances under which a particular craft technology could solve different, yet intuitively similar, problems. Thus each solution is essentially unique while the domain of its applicability remains unknown. From the point of view of scientific knowledge, the process realizing the desired state of affairs by solving the corresponding technological problem may be regarded as a 'black box' (Arageorgis & Baltas, 1989, p.213).

> The wheel also illustrated a nice absence of relation between technology and science, for why does a wheel make it easier to move a load? The answer is moderately subtle: the wheel reduces the friction between the object moved and the ground. Most of the work required to move an object over a surface is needed to overcome friction between the object and the surface. By using a wheel, the friction is reduced both by having an axle which is smooth and so reduces friction and by introducing a rolling motion at the surface. But that understanding, based on science, is completely unnecessary for either the invention of the wheel or the appreciation of its usefulness (Wolpert, 1992, p.29).

Nevertheless, the evolution of science and the evolution of technology cannot be described in terms of two parallel timelines, given that the two fields gradually began to interact. The development of connections between S&T eventually started to take shape and this issue is discussed in terms of two perspectives that are reviewed in this section. The first of these perspectives relates to the input provided by scientific knowledge in any technological development and it is discussed as the technology as applied science (TAS) perspective. According to the other perspective, any development in science relies on technological innovations; this is discussed as the materialistic perspective. Next, we discuss these two perspectives and we draw on examples from the history of S&T.

3.2.1. The contribution of science to the development of technology – The TAS perspective

During the 18th century, industrial processes gradually became more complex in ways that untrained people were becoming even less able to use basic techniques and older crafts. Black and Lavoisier were linked to situations where industrial inventions were derived mainly based on experience without inputs from science, while for the contributions of Davy and Faraday the balance began shifting towards the view that scientific progress provides the conditions needed for the development of technology (Derry & Williams, 1960), leading to an equation of technology with applied science.

The TAS perspective assumes that science precedes technology in that it provides the basis for the generation of technological innovations (Layton, 1993). This perception was widely supported in the 19th century by both scientists and engineers (Layton, 1993). There are many historical examples illustrating this perspective, including the developments in organic chemistry that led to the production of synthetic dye on a large scale, as well as the study of electric and magnetic phenomena that laid the foundations for electric light, electric current and transfer industries (Basalla, 1988; Wolpert, 1992). The essence of the TAS position is illustrated by the following excerpt from the statement of Vannevar Bush, US presidential advisor on science policy, in 1945:

> Basic research leads to new knowledge… It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes… are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science (Bush, 1945, pp.13-14 in Layton, 1993, p.25).

3.2.2. Criticism to the TAS perspective – The contribution of technology to the development of science

The TAS perspective seems to have prevailed in public understandings of the relation between S&T (Boon, 2006; Gardner, 1993). Nevertheless, its appropriateness has been questioned for two main reasons. The first reason rests on the idea that technology does not necessarily depend on science. As discussed in section 3.1 the history of technology provides several examples of technological inventions that were developed and refined independently of (and often preceded) any systematic activity in science[10]. Therefore technology cannot be reduced to the mere application of science. Layton (1993) refers to the case of Nathan Rosenberg, a distinguished economist who holds the view that:

> Technology … is a knowledge of techniques, methods, and designs that work in certain ways and with certain consequences, even when one cannot explain exactly why. It is … a form of knowledge which has generated a certain rate of economic progress for thousands of years. Indeed, if the human race had been confined to technologies that were understood in a scientific sense, it would have passed from the scene long ago […] The development costs of modern aircraft are so enormous precisely because we have no theories of turbulence or compressibility adequate to determine optimal configurations in advance. Extensive testing and modification based upon test results are still required […] The situation is caricatured in the

[10] For this see Arageorgis and Baltas (1989), Basalla (1988), Cardwell (1994), Gardner (1997), Gil-Perez et al. (2005), Wolpert (1992).

> epigram: the engineer doesn't know why his bridge stays up: the scientist knows why his falls down (Layton, 1993, p.25).

Many of the machines invented during the industrial revolution had no particular relation to contemporary scientific knowledge. The textile industry, which was at the heart of economic development in the 18th century, did not emerge as the outcome of the application of scientific theories. The inventions of John Kay, Richard Arkwright, James Hargreaves και Samuel Crompton, which were of crucial importance for the production of fabrics, should be attributed to craft practices than to science (Basalla, 1988).

> The discovery by the 19-year old William Henry Perkin of a synthetic dye, later marketed as Tyrian purple, was only one of a number of plausible and much quoted exemplars. To describe Perkin's work, as a President of the Chemical Society did in 1857, as a successful application of abstract science to an important practical purpose was misleading, however. Not only had the discovery been accidental, but the process of application had been anything but routine and unproblematical. The task of scaling up from a laboratory bench experiment to the first multi-step, hazard-contained, industrial synthesis, yielding a product of quality and price acceptable to a substantial market, confronted Perkin with formidable problems, not only scientific and technological, but economic, environmental and legal also (Travis, 1990) (Layton, 1993, p.24).

The case of the development of the photocopier machine is a characteristic example where the application of science was crucial since the development of 'xerography' or 'dry writing' was dependent on a sound understanding of the photoconductive properties of selenium. Nevertheless, the inventor Chester Carlson was surrounded by a sea of problems in his attempt to transform his innovative idea into a functional prototype. One of these problems was to find a material at the right size that could remove the surplus of ink dust from the selenium drum after each photocopy. The solution — fur of Australian rabbit — was found through trial and error and not through applying any scientific knowledge (Owen, 1986 in Basalla, 1988).

Another issue that further demonstrates the problematic nature of the TAS perspective is that there are certain cases in which it is the development in technology that has led to developments in science. Such cases fall under what is known as the materialistic perspective (Gardner, 1994a, 1994b), according to which, technological progress is actually necessary for and also influences the development of science. In many cases, scientists resorted to craft guilds, in order to obtain appropriate equipment needed to study the various natural phenomena (Derry & Williams, 1960). Carnot's thermodynamic principles governing the function of the steam engine, the theory of elasticity as a means for constructing models of the ether, and the effect of hydrodynamics on the vortex theories of matter are indicative examples where technological development clearly had an impact on scientific progress (Layton, 1993). Another example relates to the development of the telescope by craftsmen, much earlier than the emergence of our understanding of geometrical optics (Applin et al., 2000; Wolpert, 1992). The development of the telescope provided scientists with the ability to conduct more detailed observations and extend our understanding about the solar system.

Such important influences of technology on science have become more influential as a result of the establishment of experimental science. A core principle of science is falsification. Based on this principle, the emergence of new discrepant data typically initiates further elaboration of scientific theory. Without the use of technology, it is impossible to conduct experiments (except for thought experiments). The person who introduced experimental processes into the scientific practice and is thus credited with the establishment of modern science was Galileo Galilei (1564-1642).

The perspective of the "linear dependence" of technological innovations on science has been the topic of many studies in the history and philosophy in science. There are strong arguments in favor of Barnes's position that technologists instead of being absolutely dependent on scientific resources, they rather exploit the resources of their own culture (Barnes, 1982). "Technological development is a complex interaction of forces which build mainly on prior technical knowledge and through which alternatives are selected by the application of external criteria (Grove, 1980; Kranzberg, 1968; Langrish, 1974)" (Shrum, 1986, p.327).

3.3. The current relationship between S&T and their distinction as a diachronic element

3.3.1. Current relationship between S&T

Based on what has been mentioned in the subsection 3.2, it becomes evident that both perspectives of the interaction between S&T (TAS & the materialistic view) historically coexisted, despite the fact that prevalent conceptions about the nature of this interaction were not equally developed for the two perspectives, but were actually in favor of the TAS perspective. This can be induced from the fact that despite their coexistence, the appreciation of the TAS perspective prevailed for a long time, while the appreciation of the materialistic perspective seems to have emerged as a conceptual construct at a later stage and was used as an argument against the prevailing one-sided linear perspective of the relationship between the two fields.

Boon (2006) cites a number of researchers and philosophers of science[11] who suggest models of the interaction between S&T that "can explain cognitive change in technology without assuming that science is a prerequisite of technology" (p.30). These studies reveal the insufficiency of a linear-deterministic model of the science–technology relationship (prominence of the TAS perspective), since science does not necessarily need to lead to any corresponding technological innovation (Boon, 2006).

Summarizing the arguments against the prevalence of the TAS perspective, Gardner (1993) points out that the scientific and the technological capabilities are not identical. Technological development could use scientific knowledge as a resource but this does not imply a necessary condition. Even when technology uses scientific knowledge, the process of applying can be a very complex procedure that requires many practical capabilities that are not situated among scientific activities.

Science served an important role in technological developments during the second half of the 19th century and during the 20th century it further met the development of new technologies that were based on science. Despite the inflow of new scientific theories and data, modern technology includes much more than a series of applications of scientific breakthroughs. S&T in modern industry are equal partners where each field contributes uniquely to the success of the enterprise under consideration. Still, even nowadays it is not strange for an engineer to invent a technological solution that defies current scientific understanding or to devise an engineering activity that opens new avenues for scientific research (Basalla, 1988).

Barnes (1982) describes this shift in how the relation between S&T as the transition from the "good old days" where the hierarchical model dominated to "today" where the interactive model dominates our conceptions of this interaction. He describes the following change in the way of thinking:

> I start with the major reorientation in our thinking about science-technology relationship which has occurred in recent years. …we recognize S&T to be on a par with each other. Both sets of practitioners creatively extend and develop their existing culture; but both also take up and exploit some part of the culture of the other… they are in fact enmeshed in a symbiotic relationship (Barnes, 1982, p.166).

The above excerpt underlines the difficulty to isolate pure science from technology nowadays. Even though Barnes could be overoptimistic when proposing that the most

[11] On page 30, Boon (2006) cites the following: Layton (1971), Böhme et al. (1978), Rapp (1981), Constant (1984), de Solla Price (1984), Laudan (1984), Staudenmaier (1985), Basalla (1988), Kroes and Bakker (1992), Mitcham (1994), Smith and Marx (1994), Gardner (1997), and Ihde (1997).

important replacement has been achieved, this can be seen as a socially constructive view about S&T that fits well with his own view about the nature of their relationship.

Today we are less inclined to degrade technology as opposed to science. Instead, we recognize the equivalence in the relationship between S&T. Researchers of both fields creatively expand and develop their existing cultures, while at the same time they utilize methods that fall in the culture of the other field (Barnes, 1982).

> Technology and science could both survive as forms of institutionalized activity independently of the other, but are in fact enmeshed in a symbiotic relationship — a weak, mutually beneficial interaction, which looks much the same whichever way round it is considered (Barnes, 1982, p.168).

3.3.2. Distinction between S&T as a diachronic element

In many contemporary fields (electronics, genetic engineering, materials science), the interaction between scientists and technologists is so close, that the contribution of each one is difficult to tell apart (Gardner, 1993), and such fields cannot be categorized as exclusively scientific or exclusively technological. However, despite the strong connections that exist between them, S&T cannot be merged into a single construct (Arageorgis & Baltas, 1989; Wolpert, 1992). The distinction between the two fields has been discussed by many researchers[12] and depicted in various notions. Some of these are summarized by Williams (2002) and include the following distinctions shown in the following table.

Table 1

Diverse aspects of the value systems that characterize S&T

	Science	Technology
Goals	Pursuing knowledge	Creating solutions
Focus	Analytical	Practical
Knowledge	Production (abstract, general)	Transformation (detailed and functional)
Success	Better theories of understanding	Better products in the market
Methodology	[Discovery]	Design
Approach	[Reductionism]	Holism
Communication	Expository and symbolic	Visual and non verbal
Theories	About causes	About processes
Attitude	[Reductionalism]	Holism
Search for	Causes	Solutions
Real world	[Descriptive] laws	Interferes with natural order

The table is copied from Williams (2002).

Block parentheses were added to indicate aspects that are at variance with current understandings in science education.

[12] On this see Arageorgis and Baltas (1989), Bhaduri (2003), Gardner (1994), Schummer (1997), Williams (2002) among many others.

The close interaction between S&T justifies the claim that making sharp distinctions between the two fields is a rather complex issue. That is because each of the above criteria cannot stand alone in order to discriminate the two fields in an absolute manner. However, there is a consensus that the difference between the social purposes of S&T clearly distinguishes the two fields: science aims at producing reliable knowledge about how systems function; technology seeks to generate solutions to problems encountered by society or to develop procedures or products that respond to human needs[13]. From a methodological viewpoint, a consequent distinction is between core processes that are adopted for achieving the purposes of S&T. Specifically, investigation (i.e., variable controlling) is a core process in science, while design is a core process in technology (Lewis, 2006; NRC, 1996). The differentiations in the social purposes between S&T serve as a least distinctive criterion that is found to apply from the beginnings of the two fields until today. It goes without saying that there is room for creativity and innovation in both domains.

For instance, the research that is being conducted within the various branches of science with respect to climate change seeks to improve our understanding about the complex interactions between a range of factors relevant to these phenomena, including the variation in the ozone concentration in different regions of the atmosphere and the storage mechanisms for carbon dioxide gas, and to build models with predictive and explanatory capabilities. Contemporary technological activity in this same domain, seeks to design new products for harnessing alternative energy sources (such as improved batteries for making stored electricity accessible to cars over extended periods of time) in order to reduce human impact on climate change (e.g., through a corresponding reduction in the widespread emission of greenhouse gases). There is considerable technological activity involved in designing new processes for electricity generation from wind or solar energy (making use of long established scientific principles) and also in designing new methods for monitoring the climate change and possible consequences. The invention of improved procedures and techniques for providing advance warning of tsunami events are one example of a fairly recent technological innovation.

[13] On this see AAAS (1989), Agassi (1980), Arageorgis & Baltas (1989), Custer (1995), Gardner (1993, 1994), ITEA (2000), Jones (2006), NRC (1996).

3.4 Synopsis of the main ideas

Undertaking the task of exploring the historical background of the interrelationship between S&T led to the following key ideas:

- Even though S&T are two highly interacting fields it is possible to conceive them as distinct fields that differ in certain respects. For instance sections 3.1 and 3.3.2 suggest a difference between S&T in terms of the purpose they are targeted at: science could be conceived as the enterprise that seeks to generate reliable knowledge; technology is the enterprise that seeks to respond to human needs by developing solutions to problems. Consequently, the central processes that serve these different purposes are also different: investigation is a core process in science; design is a core process in technology.
- S&T today, constitute two closely linked areas of human activity, which are strongly interdependent, providing a scientific underpinning to modern technological processes and a technological underpinning to modern scientific processes. More specifically:
    - Science contributes towards the development of technology through (a) providing background knowledge (theories, laws, models) that could inform and support the design of technological innovations, and (b) posing challenges (to be seized by technology) regarding the design of novel instrumentations (i.e., the instruments/procedures for measuring, monitoring or controlling).
    - Technology contributes to the development of science by: (a) facilitating experimentation, through the provision of more reliable and accurate techniques and instruments and (b) generating new research questions whose treatment invites scientific inquiry.

We hold the view that articulating the above ideas contributes towards achieving the purpose of the present study since these ideas guide the process of curriculum design for promoting students' awareness of the interrelationship between S&T with respect to framing the teaching content.

4. The underlying rationale and a proposed structure for a teaching approach

Despite its complexity, the issue of how S&T differ and relate to each other entails certain aspects which could be usefully and productively addressed in school science, starting from the elementary school. Two of them, which are the foci of the teaching innovation we elaborate in this section, include (a) the distinction between S&T on the basis of the nature of the goals they pursue and the processes through which they seek to realize them and (b) certain aspects of the interaction among the two fields, namely that science contributes towards the development of technology by providing background knowledge (theories, laws, models) that could inform and support the design of technological innovations, and that technology contributes to the development of science by facilitating experimentation, through the provision of more reliable and accurate techniques and instruments and also by generating new research questions whose treatment invites scientific inquiry.

4.1. Underlying rationale of the activity sequence – Teaching transformations – Learning objectives

As was elaborated in a previous subsection, despite the importance of the ability to distinguish between S&T, it is the case that it does not typically emerge as an outcome of conventional science teaching or students' maturation or acquisition of experiences as members of modern societies. Obviously, this discrepancy calls for teaching innovations. As is the case with any attempts to transfer ideas about the NOS in school science, teaching innovations often need to rely on teaching transformations seeking to align the complexity of the targeted ideas with students' cognitive resources. One challenge that is inherent in attempts to devise teaching transformations for the NOS is how to avoid conflicts with corresponding ideas that are widely accepted within the philosophy of science. That is, despite being simplified and incomplete, the ideas that students are intended to develop should have the potential to serve a productive role and should be amenable to further elaboration at subsequent stages so as to become more sophisticated and epistemologically coherent (Taber, 2008). In this section, we propose an activity sequence that has been developed to serve as a teaching transformation for helping upper-elementary and lower secondary school students appreciate key ideas of the interrelationship between S&T.

The design of the activity sequence has relied on insights from three directions: (i) existing knowledge concerning the teaching and learning about the NOS (section 2), (ii) insights from the history and philosophy of science with respect to the interrelationship between S&T and its temporal evolution (section 3), and (iii) empirical data concerning students' ideas and difficulties about the distinction between S&T as reported in a specially designed study (see Constantinou et al., 2010a) (section 2).

The learning objectives addressed by the activity sequence include the development of students' understanding about (a) the distinction between S&T in terms of the core objectives they are pursuing, i.e., understanding that science seeks to generate reliable knowledge about how nature works, while technology strives to generate solutions that address human needs and problems, (b) the distinction between S&T, in terms of the core processes they rely on, i.e., investigation is a process employed for achieving scientific goals, while design is a procedure applied for reaching technological goals, (c) the potential contribution of science to the development of technology through the provision of a knowledge basis that can support the development or the improvement of technological innovations, (d) the potential contribution of technology to the development of science through, firstly, the provision of better (more accurate and more reliable) measurement instruments and experimental techniques and, secondly, the provision of new avenues for scientific investigation.

The activity sequence introduces S&T as two purposeful social enterprises. Initially, the goals and processes of the two fields are discussed separately while, at a subsequent stage, an attempt is made to combine them so as to facilitate the exploration of their interconnections. Additionally, the activity sequence incorporates activities that take into account anticipated student difficulties so as to offer them guidance to resolve them.

4.2. Overview of the activity sequence

The TLS we have developed is situated in the context of lenses and optical instruments. We deemed this as an appropriate context since it provides rich examples for the interplay between S&T such as the case of the telescope (Chalmers, 1999; McComas, 2008). The teaching approach we assumed draws on the *Physics by Inquiry* pedagogy (McDermott & the Physics Education Group, 1996). In this approach, teaching does not include any lecture, but is conducted through small autonomous, group investigations. Students work in groups with the activity sequence supporting them to gradually formulate operational definitions about S&T. Throughout the activity sequence students are systematically engaged in explicit, reflective epistemological discourse[14] with respect to the distinction between the two fields and their interconnections. For most of the time, students work in groups of three under the guidance provided by the activity sequence and the teacher. Specific points of the activity sequence include discussions between each group and the teacher as well as some whole class discussions. The activity sequence entails three sets of activities, as shown in Figure 1.

[14] For this see Akerson and Hanuscin (2007), Khishfe and Abd-El-Khalick (2002), Lederman (2007), Peters (2012), Sandoval and Morrison (2003), Walker and Zeidler (2003).

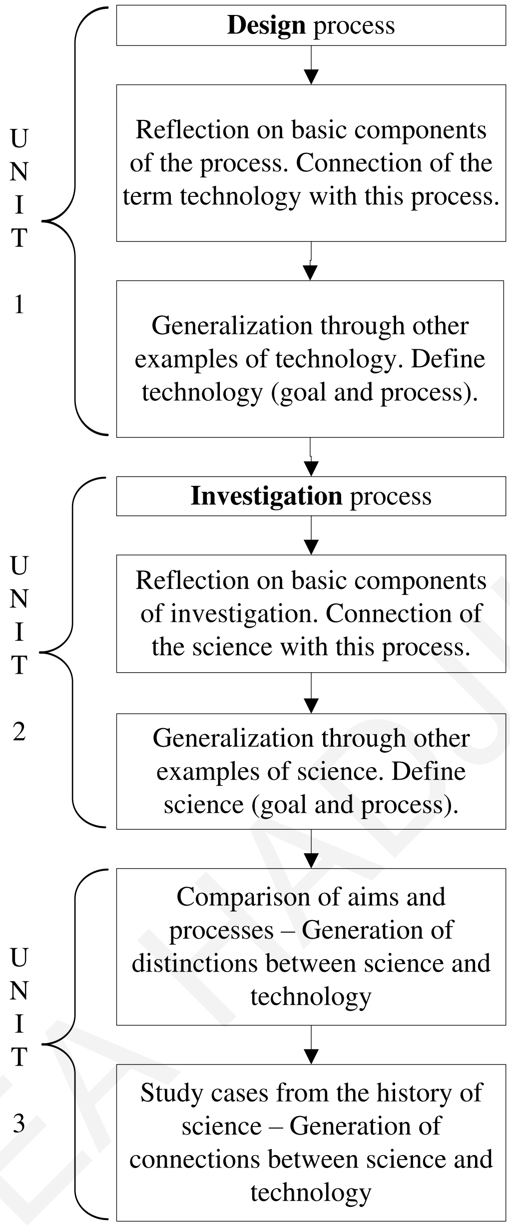

Figure 1. Structure of the activity sequence

4.2.1. Unit I: technological design process

In the first two Units students are assigned the role of 17th century researchers that work on two independent projects. In the first Unit, students go through a design process in order to develop a solution to a certain problem which involves the ability to make observations from a distance. Specifically, this problem refers to the need of a doge to watch and track his game from a distance so as to avoid disturbances. Within this mission, they are guided to identify the problem and specify the specifications that should be provided by the solution (e.g., magnification of distant objects, light to carry, easy to use, etc). A discussion with the teacher follows about what their mission is, the characteristics that should be possessed by the solution, and the resources they need for reaching a good solution. Next, students study various information that are supposed to be found in a 17th century optical instrument library concerning the use of lenses and mirrors (e.g., microscopes, periscopes, telescopes, kaleidoscopes, etc) and they are asked to find a solution that fits the characteristics they had specified. Once students decide the solution that best fits their specifications they discuss it with the teacher. Next, the teacher provides them with instructions and materials that will help them construct their own telescope. Afterwards, they are guided to use the telescope in order to assess its ability to magnify distant objects (which is the main specification that their solution should satisfy) and evaluate it by comparing with telescopes constructed by other groups (each group is given different pairs of lenses so as to result in telescope models of different magnifications). They are also asked to suggest changes that they might do in order to improve their telescope and respond more effectively to their mission.

After this mission is completed, students are engaged in reflection on the process they followed to address the problem they were confronted with (i.e., they undertake a design project) and they were guided to identify core components of this process (problem definition, formulation of specifications, data collection, suggested ideas/solutions, selection of the best idea, construction of the solution, evaluation, revision). In the next instance, they are engaged in generalizing these ideas by presenting them with descriptions of similar research processes in different contexts and engaging them in the identification of similarities with the process they followed. The aim of this latter activity is to help students to abstract core ideas relevant to the design process.

In addition to focusing on the process, students are also provided with descriptions of the goal pursued by various research projects and they are asked to identify goals that are similar to the goal they are asked to addressed in the first mission (i.e., develop solutions to human problems). At this point, the term 'technology' is introduced for the first time and it is associated with the goal of developing solutions to human problems and the design process. It is important to note that, at this stage, the design project that was implemented by students did not rely on scientific knowledge (the contribution of science will be advanced later on). This decision is made for two reasons. The first is that this allows attributing to technology a possible self-existent status and partially addressing students' difficulty in viewing technology as applied science. Secondly, this could serve to avoid the premature appearance of the science-technology distinction which would have perplexed rather that enhanced students' understanding of the issue at this stage.

4.2.2. Unit II: Scientific investigation

Similarly, the second Unit seeks to help students appreciate the goal of science (i.e., generation of reliable knowledge) and recognize investigation as a process through which it seeks to realize this goal. This is achieved through students' engagement in structured investigations that evaluate the potential influence exerted by various factors on the magnification provided by a lens. This set of activities is carried out in terms of the students' second mission, where they are trying to respond to Galileo's need to improve his understanding about how his telescope works. As was the case with the previous unit, the role of technology and its relation to science was intentionally excluded from the discussion. More specifically, students initially formulate operational definition about the focal length of a convex lens (i.e., the distance between a lens and a piece of paper in which the paper burns if the lens is placed between sunlight and the paper). Next, students carry out two structured investigations in order to respond to questions posed by Galileo ("Does the distance between an object and a lens influence the distance between a lens and its image?", "Does the focal length of a lens influence the dimensions of a very distant object's image?"). Next the teacher discusses with the students how the findings that emerged from their experiments are connected to the operation of the telescope and they are asked to rely on them for formulating instructions, to be sent to Galileo, on how to carry out experiments in order to investigate whether the focal length of an objective or an eyepiece lens influences the image produced by a telescope.

Next, students are supported to reflect on the process they followed through questions that help them identify certain aspects as basic components of investigation (formulate investigable question in the form "Does factor A influence factor B?", carry out the experiment (change factor A, measure factor B, keep constant all other factors that might influence), record results, answer the investigative question). They are also guided to generalize the objective served by such research processes (i.e., develop understanding about how nature functions) by providing them with various research goals of other projects and asking them to identify those that are similar, in nature, with the goal they addressed themselves. At this point, the term 'science' is introduced for the first time and it is connected with the goal of producing reliable knowledge about how nature works and the investigation process.

4.2.3. Unit III: Distinctions and relationships between S&T

After reaching consensus about the goal and core processes of each domain, students are gradually introduced to certain aspects of how S&T interact. This Unit begins with engaging students in a discussion on the differences between S&T. Specifically, they are asked to compare and contrast the two research projects that they were engaged with, in terms of their goal and the process through which they seek to realize them. Students are guided to construe the nature of the goal (production of new knowledge versus identification and development of solutions to certain problems) and the core process for realizing goal (investigation versus design) as two ways of distinguishing between S&T.

Next, students review narratives that have been specifically formulated so as to depict examples of interaction between S&T[15]. Those narratives are presented as parts of a fictitious diary that was supposed to belong to Galileo and students are asked to identify examples of scientific and technological activities and also identify instances in which science contributed to the development of technology, or vice versa. This is intended to help students appreciate the bidirectional relationship between S&T. Examples of these excerpts are shown in the following Figure.

> […] "Since I was informed about the existence of telescopes, I am very curious in understanding how a telescope functions so as to magnify distant objects. How do its lenses function? Does the focal length of a lens influence the magnification of the telescope? Tomorrow morning I will do some investigations with different lenses so as to explain how the telescope works…"
>
> "Today I carried out two investigations. In the first, I investigated whether the focal length of the lens influences its magnification, i.e., how many times a distant object is magnified. I constructed telescopes with different objective lenses. I used them to observe the Moon and I calculated the magnification for each telescope. I reached the conclusion that the longer focal length of the objective lens, the bigger the objects seemed. In a similar manner, I carried out a second investigation […] From the results I concluded that the smaller the focal length of the eyepiece lens, the higher the magnification."
>
> "Dear diary, the conclusions from yesterday's investigations have helped me in deciding which lenses I should use in order to make a strong telescope" […]
>
> "During the last few nights I used my telescope in order to observe the stars. To my great surprise, I observed various things that are not visible by the naked eye. I observed that the Moon's surface is not smooth but consists of mountains, valleys and many craters. Also, I noticed that the shape of planet Venus changes each night just like the Moon does. I even saw that planet Zeus has its own moons and not one, but four! I will continue my observations because now I am even more interested in understanding how the planets move."

Figure 2. Excerpts from the "Galileo's diary" that was used by students to investigate the relations between S&T

[15] For this see Abd-El-Khalick and Lederman (2000b), Irwin (2000), Olson et al. (2005), Rudge & Howe (2009), Solomon et al. (1992), Straits and Nichols (2007).

5. Discussion – Teaching and curriculum design implications

Possessing an adequate understanding concerning how S&T differ and interrelate has implications on various issues including citizens' ability to meaningfully participate in the public debate over socio-scientific issues and make informed choices on their future careers. In this study we have illustrated a teaching proposal for raising young learners' awareness of the interrelationship between S&T. A major source of input that was assumed and employed in designing the TLS was the history and philosophy of S&T. Specifically, we have undertaken the task of mapping the various perspectives expressed in the relevant literature on the relation between S&T with a view to use this body of information for guiding the curriculum development process. The study's main contribution is twofold.

The first relates to highlighting the potential of using inputs from the history and philosophy of science on perspectives of the interrelationship between S&T. This serves as a useful tool for facilitating and supporting attempts to develop teaching and learning materials that address NOS issues. Specifically in our case, exposing the perspectives of the interrelationship between S&T through the lens of history has revealed the complexity inherent in the whole issue and especially in pursuing clear distinction between these two fields in the context of contemporary interdisciplinary research fields. This analysis has provided valuable insights that have largely informed the development of the activity sequence. Specifically, it served towards clarifying core ideas and, hence, it informed decisions relevant to the formulation of learning objectives and to the design of the activity sequence so as to be based on appropriate transformations of the actual content of the interrelationship between S&T. For example, mapping the historical background of the two main perspectives of the interaction between S&T (TAS and materialistic perspective) has contributed to the identification of certain ways in which advancements in one field contribute to the development of the other, which were taken into consideration for the formulation of the corresponding learning objectives.

At the same time, the lessons learned from mapping the historical background around the certain perspectives of the interrelationship between S&T served to articulate the teaching transformation, by identifying the constraints that is bounded with and ensuring its potential to be elaborated at subsequent stages so as to address these constraints and become more closely aligned with how S&T are construed in the corresponding academic fields. For example, it is the case that ascribing technology and science with a self-existent status in Units 1 and 2, respectively, seems rather inaccurate and incapable of capturing the interdisciplinary nature of contemporary technological and scientific research. However, despite this limitation, it has to be stressed that this approach provides an appropriate starting point for facilitating the discussion on the interrelationship between S&T: it enables students to familiarize themselves with fundamental characteristics of each field individually (i.e., the goals they are pursuing and the core processes they rely on in realizing these goals), which is a prerequisite for explicitly engaging in epistemological discourse about differences and connections between S&T. This initial approach could be further elaborated at subsequent stages so as to incorporate additional aspects of the corresponding issue and shift to a more informed account (Taber, 2008). At this point, in addition to its potentially productive function, it is also interesting noticing the compatibility between this approach and the corresponding historical perspective that is evidenced in section 3.1 concerning the initial independence between S&T. Even though the discussion about the value of drawing on history and philosophy of science as a resource for curriculum development has been restricted to a specific aspect of the NOS (i.e., the interrelationship between S&T), it is important noting that this could be generalizable to any attempt to devise curriculum materials for addressing learning objectives relevant to the NOS.

The second contribution of the present study relates to the proposal of the structure of a teaching innovation for addressing this issue with elementary students. Despite the wide recognition of the importance of helping students develop epistemologically informed views about the NOS[16] this learning objective typically receives scant attention in conventional teaching practice in science and there is a need for relevant research-based teaching innovations for integrating explicit aspects of the NOS (Lederman, 2007; McComas, 2002; Sandoval & Morrison, 2003), especially in the case of the elementary and middle school grades (Akerson & Volrich, 2006; Kang et al., 2005). The present study contributes towards meeting this need by proposing an activity sequence for developing students' awareness of a specific NOS aspect, namely the interrelationship between S&T.

Future steps of the current research project include the implementation of the activity sequence in classroom environments with a view to evaluate its effectiveness through appropriate instrumentation and to further promote its learning objectives.

[16] For this see AAAS (1989), Driver et al. (1996), Kang et al. (2005), Lederman (2007), NRC (1996).

CHAPTER III

Teaching aspects of the interrelationship between science and technology: a research report on the design, enactment and evaluation of a teaching proposal

Abstract

Helping upper-elementary and lower-secondary school students develop an awareness of various aspects of the nature of science and technology is a widely recognized goal of science teaching. In this study we focus on the interrelationship between S&T. We report on the design development, implementation and evaluation of a TLS that combines hands-on activities in geometrical optics with EED for reflection purposes. The design of the TLS drew on perspectives from inquiry-oriented and design-based teaching and learning frameworks. The enactment of the sequence involved an intact class of upper-elementary school students. We present indicative results from written closed-ended and open-ended tasks and follow-up semi-structured interviews about students' understanding of the difference between the overarching goals of S&T. The results illustrate elementary students' readiness to engage with epistemic issues and demonstrate possibilities in prompting young learners' ability to develop informed awareness of the nature of S&T. The results also provide feedback for the revision of the TLS so as to further enhance its effectiveness in achieving the stated learning objectives. We discuss implications for the teaching of nature of S&T ideas and for the design and validation of TLSs.

Keywords

teaching-learning sequence; nature of science; explicit epistemological discourse; science and technology

1. Introduction

Whilst the Nature of Science (NOS) and Nature of Technology (NOT) as educational constructs are recognized as core learning objectives of S&T education and an components of scientific and technological literacy (AAAS, 1989; Driver et al., 1996; ITEA, 2007; Kang et al., 2005; Lederman, 2007; McComas & Olson, 2002; NRC, 1996, 2012; Taber, 2008 among many others), conventional science/technology teaching practices pay inadequate attention to this goal. More research is needed, both for clarifying pending issues relevant to teaching and learning about NOS/NOT and for exemplifying illustrations of effective teaching innovations (Lederman, 2007; Sandoval & Morrison, 2003), especially in the upper-elementary and lower-secondary school grades (Akerson & Volrich 2006; Kang et al., 2005).

Our study responds to this need with a focus on a scarcely investigated aspect of NOS/NOT, namely the interrelationship between S&T. The interrelationship between S&T is of contemporary interest because of the societal need to make better use of the results of research in innovation and entrepreneurship. Science education can contribute towards laying the foundations for an appreciation of this priority by promoting student understanding of the distinction as well as of the connections between S&T (Jones & Buntting, 2015; McComas, 2008; Osborne et al., 2003), which are recognized as one aspect of NOS/NOT (Constantinou, et al., 2010a; Hadjilouca, Constantinou & Papadouris, 2011; McComas, 2008; Osborne et al., 2003).

It is questionable whether we could or should engage teenage students in drawing sharp distinctions between S&T. However, we do draw on the premise that trying to think about this distinction can lead to a better understanding of what can clearly be classified as Technology and what can clearly be classified as Science, as well as how the two interconnect, feeding from each other through a dynamic interaction. The study investigates sixth graders' ability to develop an awareness about this topic through a specially designed TLS. The TLS focuses on explicitly promoting learning objectives concerning the appreciation of the main aspects of the interrelationship between S&T, such as the different overarching goals of Science or Technology, the different fundamental processes pursued by S&T and fundamental ideas relating to the connections between S&T.

2. Theoretical framework: developing NOS/NOT awareness about the interrelationship between S&T

2.1 Proposed ways for teaching NOS/NOT

Research on assessing and promoting NOS/NOT understandings has led to consensus that such awareness does not develop intuitively, but needs to be explicitly addressed (Akerson et al., 2000; Driver et al., 1996; Lederman, 2007; Papadouris & Constantinou, 2017). This is empirically supported by studies that assess students' views of the distinction between S&T in particular (Constantinou et al., 2010a), as well as students' understandings of other NOS aspects (Kang et al., 2005; Lederman, 2007). All of these studies conclude that students' understandings about NOS/NOT do not emerge as a result of their interaction with conventional science/technology activities. Additionally, empirical research reports with classroom enactments where NOS was explicitly addressed, support the need to explicitly treat NOS, like all objectives of science learning, through purposefully designed activity sequences (Khishfe & Lederman, 2006; Lederman, 2007; Sandoval & Morrison, 2003).

Explicit teaching of NOS refers to purposefully planned group discourse activities that draw students' attention to epistemic issues (Oliveira et al., 2012). Prior research on investigating explicitness in NOS teaching examines the role of systematically engaging students in reflective and structured discussions. Relevant literature suggests that embedding such EED improves NOS understanding (Clough, 2006; Lederman, 2007; Sandoval, 2003). However, this approach has not been examined with respect to the interrelationship between S&T.

Research reports suggest three possible types of activities for explicitly promoting NOS understandings in science teaching/learning. These three types vary depending on the extent and type of integration with other aspects of science learning. The first type, suggests *nonintegrated/de-contextualized activities* wherein the elaboration about NOS is disconnected from the science topic under study (e.g., Lederman & Abd-El-Khalick, 2000; Bell, 2008); the second type refers to *integrated/contextualized activities* that embed epistemic aspects of science in the same activities that are intended to elaborate the conceptual aspects of the scientific context (e.g., Khishfe & Lederman, 2006; Walker & Zeidler, 2003; Zeidler et al., 2002); the third type pertains to *studying episodes drawn from the history of science* with a view to abstract epistemic ideas (e.g., Clough, 2011; Kim & Irving, 2010; Rudge & Howe, 2009; Solomon et al., 1992).

These approaches have not been extensively studied yet and further research is needed on their relevant effectiveness. Notably, only three comparative studies reported heretofore, compare integrated and non-integrated approaches (Bell et al., 2011; Khishfe & Lederman, 2006; Peters, 2012). The results of these three studies do not clearly suggest the adoption of a single approach, since moderate improvements in students' NOS awareness were found in all types. We have been unable to identify studies that compare the effectiveness of promoting NOS understandings through stories from the history of science and the use of the integrated or the nonintegrated approach. Our study is mainly aligned with the integrated approach, although it embodies episodes from the history of science.

2.2 Why is an awareness of the interrelationship between S&T important?

Focusing on the interrelationship between S&T is justified for various reasons, also elaborated elsewhere (Constantinou et al., 2010a; Hadjilouca et al., 2011). The most important of these can be summarized as follows: Firstly, as previously mentioned, it is recognized as one aspect of the NOS/NOT (McComas, 2008; Osborne et al., 2003). Secondly, it has not been adequately studied heretofore, especially in the case of K-8 school students (Akerson & Volrich, 2006; Kang et al., 2005). Thirdly, appreciating the potentials and constraints of S&T is essential for developing the ability to effectively engage with socio-scientific issues (Sadler et al., 2005), which is a recognized, important component of both scientific and technological literacy (AAAS, 1989; Jones, 2006; ITEA, 2007; Kolstø, 2008; Sandoval, 2005). Fourthly, new knowledge in this area could inform and facilitate attempts to devise mechanisms for increasing students' interest towards S&T courses (Gago, et al., 2004; NSF, 2003; OECD, 2006) and it could offer them guidance on future careers (Jones & Buntting, 2015). Particularly, it could help the education system encourage students to make more informed decisions and in turn, increase the likelihood for successful career choices. Finally, prevalent conceptions about S&T are important for efforts to communicate publicly their role in society and the outcomes of the various policy procedures for developing funding priorities. For instance, the level of public support for an innovation system in close symbiosis but distinct from the science system, and also closely related with financial investment mechanisms, is directly related to the level of public understanding of the differences between S&T and the diverse roles they play in economic development.

2.3 Operational definitions for this research

S&T are two highly interacting fields of social activity. Nevertheless, it is possible to consider them as distinct domains. A fundamental difference between S&T, which is the focal point of the enactment reported in this study, relates to the difference in the orientation, i.e., between the overarching goals that the two field pursue: Science is the enterprise that seeks to generate reliable knowledge; technology is the enterprise that seeks to respond to human needs by developing solutions to problems (AAAS, 1989; Arageorgis & Baltas, 1989; Constantinou et al., 2010a; Bybee, 2011; Gardner, 1994a; ITEA, 2007; Jones, 2006; NRC, 1996). Furthermore, from a methodological viewpoint, another distinction refers to the core processes adopted for achieving the different goals of S&T. Specifically, controlled experimentation or, more broadly, investigation is a core process in science, while design is a core process in technology (De Vries, 2009; Jones & Buntting, 2015; Lewis, 2006; NRC, 1996, 2012; Constantinou et al., 2010a).

Controlled experimentation[17] is a specific methodology employed in scientific research with the objective "to test hypothesized links of causation or functional relationships, that is, tentative explanations" (Gyllenpalm & Wickman, 2011, p.4). This methodology could be enacted when studying causal relationships between variables that might be involved in a phenomenon. It includes the performance of a specific planned change in a system and the study of its effects, while simultaneously as many extraneous variables as possible are kept constant (Beveridge, 1961). Controlled experimentation can be thought of as one approach to scientific investigation. An understanding of controlled experimentation combines both conceptual and procedural aspects, which are important facets of scientific thinking (Duggan & Gott, 1995).

In this simplified transformation, the methodological aspects of technology can be described by the construct of design. Design rests on a set of attributes that can be iteratively combined in order to devise a solution to a problem, that corresponds to an end product or a process, which satisfies certain specified requirements. Such attributes include the following: Definition and representation of the problem, formulation of specifications, search for relevant information, brainstorming of ideas and planning, selection of the best idea, development of a model of the selected solution, test and evaluation of the model of a solution, refinement, usability test, communication of results (ITEA, 2007).

It is important to recognize that the processes employed in S&T are much more complex and obviously not restrained exclusively to controlled experimentation or design, respectively. Nevertheless, these two processes are core representative features of the two domains and therefore can serve as starting points for teaching about the distinction between S&T (Hadjilouca et al., 2011).

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[17] Also reported as *control of variables strategy* (D. Klahr, D. Kuhn), *design and conduct of scientific investigations* (D. Kuhn, N. Lederman), *experimental design* (N. Lederman).

Developing awareness about the interrelationship between S&T posits an interesting challenge for S&T education. Given the complex nature of both enterprises, their interconnections and mutual influences are predictably elaborate. For the purposes of school teaching and learning, the following simplified account provides a structure for rich and fruitful development: S&T constitute two closely linked areas of human activity, which are strongly interdependent, providing a scientific underpinning to modern technological processes and a technological underpinning to modern scientific processes. Specifically, science contributes to the development of technology through (a) providing background knowledge (theories, laws, models) that inform and often guide the design of technological innovations, and (b) posing challenges (to be seized by technology) regarding the design of novel processes or instrumentation (i.e., the instruments/procedures for measuring, monitoring or controlling). Respectively, technology contributes to the development of science by (a) facilitating experimentation, through the provision of more reliable and accurate methods and instruments and (b) generating new research questions for scientific inquiry.

The TLS developed in this study for promoting upper-elementary school students' awareness of the interrelationship between S&T, emphasizes on these dual ideas: mutual support and interacting requirements between S&T.

3. Research questions

In this study we wanted to focus on students' understanding of the difference between the overarching goal of science and the overarching goal of technology. Specifically, we sought to investigate the following research questions:

(a) To what extent can upper-elementary school students improve their understanding about the different overarching goals of S&T through a specially designed TLS that combines inquiry-oriented and design-based activities integrated with explicit NOS/NOT discourse?

(b) What difficulties do upper-elementary school students encounter in their attempts to develop an understanding of the difference between the overarching goals of S&T?

4. Development of the teaching proposal

The research followed a technological design process that included: a) initial design of the activity sequence, b) enactment with a class of sixth grades, c) pre-post tests and follow-up interviews for assessing students' understanding, d) data analysis, e) refinement of the activity sequence based on the results. This process is shown in the figure below.

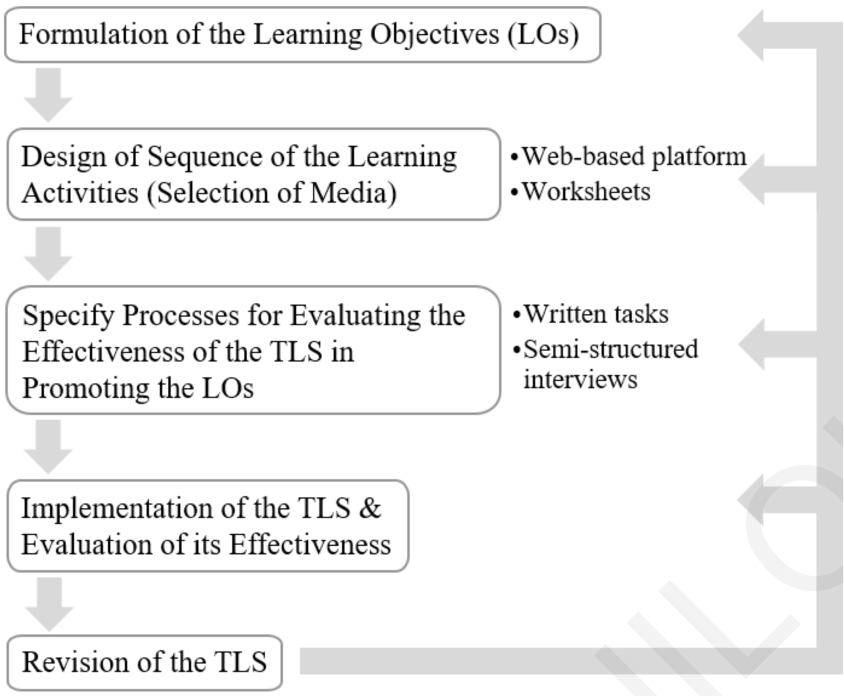

Figure 3. Development of the teaching proposal

4.1 Formulating the Learning Objectives (LOs)

The first stage of the development of the TLS involves the formulation of LOs. Specifically, the LOs include elaboration on the following two aspects of the interrelationship between S&T: (a) the differences between S&T on the basis of the nature of the overarching goals they pursue and the central processes through which they seek to realize them and (b) certain aspects of the interaction among the two fields, namely that science contributes towards the development of technology by providing background knowledge (theories, laws, models) that could inform and support the design of technological innovations, and that technology contributes to the development of science by facilitating investigation, through the provision of more reliable and accurate techniques and instruments and also by generating new research questions whose treatment invites scientific inquiry.

4.2 Designing the activity sequence

4.2.1 Inputs

This initial design was based on two types of input: theoretical and empirical. The first, concerns the review of literature from relevant areas from the History and Philosophy of S&T such as facets of the interrelationship between S&T and from Science Education such as proposals for teaching NOS topics, approaches used for assessing students' NOS understanding and methodological issues in curriculum development. A previous study was concerned on this type of input (Hadjilouca et al., 2011). The second, concerns empirical input about of various aged students' ideas and difficulties about the distinction between S&T, again investigated in a previous research (Constantinou et al., 2010a).

4.2.2 Rationale and overview of the activity sequence

The teaching approach enacted applies the "physics by inquiry" pedagogy (McDermott & the Physics Education Group, 1996). In this approach, teaching does not include any lecture, but is conducted through small autonomous, group investigations, where the teacher facilitates learning through posing questions and probing students' reasoning. For most of the time, students work in groups of three under the guidance provided by the activity sequence and the teacher. Specific points of the activity sequence include discussions between each group and the teacher as well as some whole class discussions. Throughout the activity sequence students are systematically engaged in explicit, reflective epistemological discourse with respect to the LOs, so that they gradually formulate operational definitions about the S&T. For the design of the first set of activities, students used a web-based environment, while the rest of the activities were based on using worksheets and experimenting with real materials.

The rationale of the TLS involved the gradual implementation of the orientation and the main methodology introduced in each of the two fields and at a later stage the expansion on explicit study of connections between S&T. Additionally, the TLS included purposely designed activities so as to manage expected students' difficulties and to support students for overstepping them through discussions of each group with the teacher and whole class discussions.

4.2.3 Conceptual context and activity structure of the TLS

Lenses and optical instruments are the conceptual context for addressing the LOs and historical episodes from the history of the telescope are included. Lenses and optical instruments is considered as an appropriate context for situating the TLS, since it provides rich examples of the interplay between S&T, such as the case of the telescope. The activity sequence entails three sets of activities, as structured in the following figure and in the following paragraphs. More detailed information on the rationale of the combination of inquiry-oriented and design-based activity sequence can be found in Study 1 (Hadjilouca et al., 2011). The present study is the first attempt to apply the rationale and explore its effectiveness with respect to promoting the LO about understanding the distinction between the overarching goals between S&T.

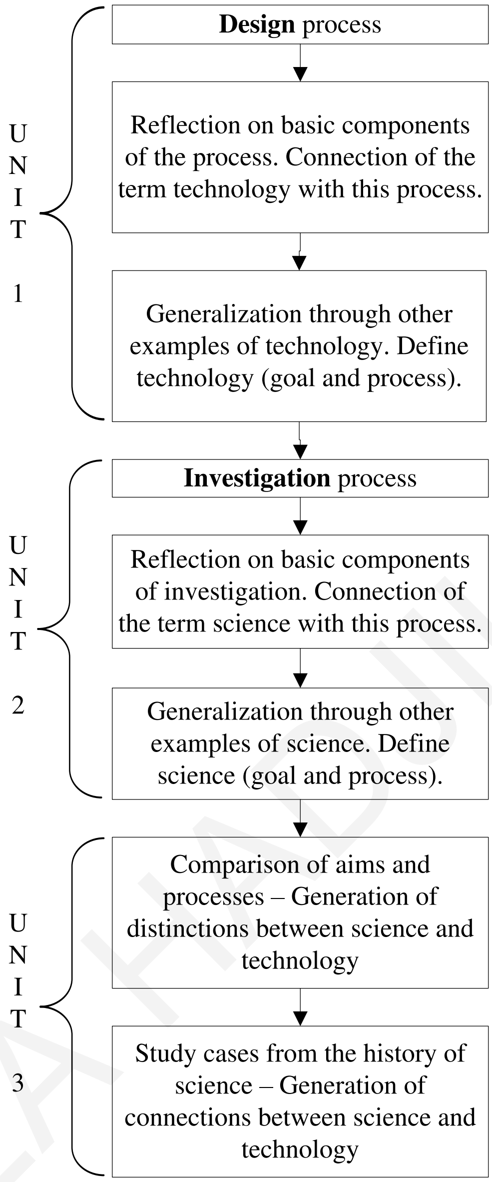

Figure 4. Structure of the activity sequence

The above conceptual structure of the TLS is an overview of the activity sequence. According to this, students learn by doing and reflecting while engaging in explicit epistemological discourse, through sets of activities.

In the first set (Unit 1), students go through a design process in order to develop a solution to a certain technological problem (i.e., to help a hunter so that he can watch and track his game more easily). Afterwards they are supported to reflect on the process they followed and, in the next instance, they are given descriptions of a similar design process in a different context with a view to help them identify certain aspects as basic components of technological design. They are also guided to generalize the objective served by such design processes (i.e., develop solutions to human problems) through providing them various research goals and asking them to identify cases where a research goal is similar to theirs or not. At this point, the terms of ‘technology’ and ‘design’ are introduced for the first time and the field of technology is connected to its overarching goal and central process.

The second set (Unit 2) includes activities where students experimentally study factors that influence the magnification of lenses. Afterwards, similar to Unit 1, the activities seek to scaffold students to reflect on their activities and gradually generalize the goal of science (i.e., generation of reliable knowledge) and recognize investigation as a process through which it seeks to realize this goal.

In the first part of Unit 3, students are asked to compare and contrast the two research projects (Science and Technology projects) they accomplished in terms of the ways they worked and therefore appreciate two possible ways of distinguishing S&T; the nature of the aims they targeted at and the processes through which they enacted them.

In the second part of Unit 3, students review case studies from the history of the development of the telescope and they are guided to identify situations in which science contributes to the development of technology, or vice versa. This is intended to help students appreciate aspects of the bi-directional relationship between S&T.

4.3 Specifying processes for evaluating the effectiveness of the TLS in promoting understanding of the different overarching goals between S&T (Evaluation tasks)

Participants were an intact class of 17 sixth grade students aged 10-11 years old of a public elementary school. The TLS was enacted in the context of their S&T classes for a period of five weeks in which students met with the teacher/researcher for twelve 80minute sessions.

Before and after the enactment, students were assessed through forced-choice and open-ended tasks. In addition to this, ten of the students also participated in follow-up pre/post semi-structured interviews (protocol is attached in Appendix D). In this study we only report results from two of the written tasks, one quantitative and one qualitative, which assessed students’ understanding of the distinction between the overarching goals of S&T. We also report results from the interviews.

The first evaluation task (attached in Appendix B) involved completing two tests that were designed so that their items work in parallel and they were administered sequentially in one session. Each of these tests consisted of 32 multiple choice items, with each item describing the main objective of a certain research project. Students were asked to categorize these descriptions using a given criterion. In the first test (formal terminology, FT), they were asked to determine whether the stated objective of each project was more closely aligned with the goal of science, technology or neither. In the second test (elaborated definitions, ED), they were asked to differentiate between projects whose objective either involved the improvement of our understanding with respect to the behavior of some aspects of the natural world (e.g., We examine whether microwave ovens are dangerous for our health and also what sort of problems they might cause), or the development of solutions to problems encountered by society (e.g., We try to make filters to absorb polluting fumes that are emitted from factory chimneys), or neither of these two goals (e.g., We are trying to decide the best location to build a desalination plant). Noticeably, these two sets of criteria are equivalent in that the second set draws on the core objectives of S&T. Underpinning the combined use of FT and AD tests is the idea that students who are in a position to differentiate between S&T in terms of the objectives that both fields pursue, would respond to both tests in a similar manner. Thus, the correlation of students' responses to the two tests was anticipated to assess their awareness of this specific aspect and, hence, provide a measure of their understanding of the distinction between S&T, in general.

The second evaluation task concerns an open-ended question that was completed at the end of FT test (before ED) and asked students to come up with a general statement on how one could determine whether a research project seems either technologically or scientifically oriented.

Follow-up semi-structured interviews with 59% of the participants, were intended to help us describe students' reasoning and identify possible epistemic or other difficulties hampering their learning pathways. Each interviewee was asked to respond (for a second time) to a selected sample of items included in the two written tests of the first evaluation task and next explain his/her reasoning. Additionally, whenever the interviewer identified inconsistencies (e.g., cases in which interviewees provided incompatible responses to the various items or responded differently as compared to the written test), she explicitly confronted students with these discrepancies and asked them to elaborate on them. These interviews are intended to provide a more detailed account of the reasoning underlying the student responses. This is also anticipated to inform our interpretation of data from the open-ended question of the FT test, in which students are explicitly asked to explain their reasoning (Lederman et al., 2002).

5. Enacting the TLS and evaluating its effectiveness - Results

5.1 Students' understanding of the distinction between the overarching goals of S&T

The effectiveness of the TLS in scaffolding students to appreciate the distinction between the overarching goals of S&T is evaluated through various measures: One such measure is the correlation coefficient *r* between the scores in the FT and ED tests (r_{pre}=0.351, p_{pre}=0.167

and r_{post}=0.715, p_{post}=0.001). After the enactment, the correlation coefficient was higher and statistically significant, while the opposite was found before the enactment.

Another measure pertains to students' performance in each of the two tests before and after the enactment. Paired samples T-test[18] yielded statistically significant differences in students' performances for both tests before and after the enactment, (FT test: $t(16)=2.124$, $p<0.05$, ED test: $t(16)=5.491$, $p<0.001$), with large effect sizes ($r_{FT}=0.468$, $r_{ED}=0.808$). Therefore, students' response to the two tests and therefore their appreciation of the distinction between S&T changed as a result of the enactment.

Table 2
Students' responses to the question 'How do you determine whether a given research project is more scientifically or more technologically oriented?'

	Description of category	Typical student responses	n=17 pre	n=17 Post
0	Irrelevant answers – No response	'In science we do scientific stuff and in technology we do technological stuff.'	7	2
1	Inadequate or ambiguous discrimination	'Technology is something that develops, while science is something that we discover.'	6	6
2a	Discriminating based on the methods that appear in each domain	'A project belongs to science when we do an experiment. A research project belongs to technology when we construct something.'	1	0
2b	Discriminating based on the object of study in each domain	'When it contains terms that relate to nature, the research belongs to the field of science. But when it relates to inventions made by people, then it belongs to the field of technology.'	1	0
3	Discriminating based on the goal of each domain	'A project belongs to science when it deals with natural phenomena and studies them in depth to establish conclusions. A project belongs to technology when it tries to find solutions to address human problems and improve our life conditions.'	2	9

Data collected through the open-ended task were exposed to phenomenographic analysis (Marton & Booth, 1997; Østergaard et al., 2008) in order to formulate ordered categories of responses. The categories are shown in the table above and each one is illustrated through a typical student response along with frequencies found before and after the enactment. In the *lower (zero) level*, we have irrelevant or no responses. In the *first level*

[18] The appropriateness of this parametric test was warranted through ensuring equal interval scaling in the FT and ED scores, on scales developed with Rasch model (Boone & Scantlebury, 2006) as part of a previous study (Constantinou et. al., 2010a) that evaluated intact students' awareness on the same issue (N=393).

we have grouped responses with inadequate or ambiguous discrimination. In the *second level* we have 2 subcategories, where the responses discriminate between S&T based either a) on the methods that appear in each domain, either b) on the object of study in each domain. In the *third level*, we have responses that discriminate between the two fields in a desirable manner, i.e., based on the goal of each field. This particular categorization was formulated in the context of a previous research that investigated students' ideas with a larger sample (Constantinou et al., 2010a) and it was applied in this case too.

The comparison of students' responses before and after the enactment, shows an important increase in the number of responses that fall under the first category, which expresses the responses that distinguish between the scientific and the technological goal in a valid manner and simultaneously decrease in the rest of the categories except category 1 that remained constant.

5.2 Difficulties encountered by students in their attempts to develop an understanding of the interrelationship between S&T

As mentioned before, the follow-up interview data intended to help in making students reasoning more clear and identify difficulties that hamper their ability to distinguish between the main orientation of science and the main orientation of technology. Our effort was informed by similar data collected in a previous study with a larger sample (N=183) of students of the same age level from intact classes (Constantinou et al., 2010a). The difficulties identified in the current study are organized in three groups according to whether they mainly relate to (a) the NOS, (b) the NOT or (c) the interaction between S&T. The grouping serves as a means to organize the presentation of the results and does not imply that difficulties in one category are mutually exclusive from the difficulties in the other categories.

One of the difficulties that in the first (NOS) group emerges from the conception of decision making as a practice that it is exclusively done by scientists. For example, two students that classified a research project that seeks to decide on the most appropriate location for a new desalination plant under the main goal of science justified their decision *'because it pertains to activities that scientists need to do before building the plant'* and *'because this is a decision to be made by scientists'*.

Another difficulty concerns students' belief that producing knowledge does not present a worthwhile task unless this knowledge contributes to the common good, by providing solutions to social problems. Typical quotes that indicate this difficultyare: *'We do research in science when we try to find the solution to a problem.'* and *'Science is when* *the researcher studies various situations in order to come to some conclusions that will be used for improving our life'*. Although this instrumental view of knowledge, is useful from the perspective of the public appreciation of science, it ignores worthwhile scientific areas of basic research and disorients from the quest to appreciate the distinction between the overarching goals of S&T.

The third difficulty relevant to the NOS refers to students' lack of understanding with respect to the role of experiments in science. Students with this difficulty view that experiments are carried out only in the realm of science and, hence, any project that refers to experiments necessarily falls under science. For example, a student said that *'when the project includes experiments conducted in a lab, then it's science'*.

Equating the mere use of scientific knowledge with the practice of science per se was another difficulty relating to NOS. These students failed to appreciate the distinction between generating scientific knowledge and drawing on scientific knowledge, which any literate citizen might be expected to do. A quote illustrating this difficulty was: *'I believe that this is an example of research in science because the researchers are collecting and using various scientific information received by the weather instruments'*.

A further difficulty of this category relates to the unarticulated exclusive notion of the term 'natural world'. This difficulty was obvious in students' failure to conceive of technological constructs as entities that, despite being artificial, still obey the laws of the natural world. Typical quotes which illustrate this difficulty are: *'scientists are studying natural objects, therefore here where they study about the cars' emissions it cannot be a goal of science'; 'It's a scientific goal because they are trying to make changes in foods. It's not a goal of technology because it doesn't relate to constructions, cars etc'*.

The last difficulty in this category adopts the view that when a research goal is a novelty –regardless if it relates to an effort for understanding or to a solution– then it concerns a goal mainly aligned to science. Some typical to this difficulty quotes are: *'It is science because it is about a topic we know little things and we need to discover it'; 'It's a scientific goal because it concerns something that no one else has ever studied.'; 'This research goal is scientific because it tries to discover something new, that is not written somewhere... it's not technological because technology is concerned with things that already exist and technological research tries to improve them'*.

The second group consists of three difficulties, which are connected to the NOT. The first concerns the confusion between *using technology* and *doing research* in technology. This difficulty, is illustrated in the following quotes: *'It is technology when we use* *computers.' and 'If the use of machines is involved in this research, then we are talking about technological research.'*

The next difficulty relates to students' failure to appreciate creativity as an integral component of research in technology and solely attribute this to science. This is demonstrated in the following quote from a student's response in the following interview quote: *'Technology relates to machines and constructing something we already knew how to do, while science relates to thinking and finding ways to construct something'.*

The last difficulty that relates to the NOT is the view of decision making as a problem solving process and hence, an example of technology. For example, a student said that *'determining the most appropriate location for the new water desalination plant belongs to technology, since it's a problem solving situation'*. This difficulty also indicates students' failure to identify design (of products or processes) as a core process in technology (De Vries, 2006).

The third group consists of two difficulties that are concerned with students' failure to appreciate the interaction between S&T. The first relates to students' tendency to differentiate between the two fields depending on whether they refer to either natural (science) or artificial (technology) entities. The following statement was commonly mentioned in similar words and is revealing of this difficulty: *'I chose the technology goal because it has to do with an artificial thing, such as microwave ovens, while scientific goals relate to things found in nature that are not artificial, such as water'.*

The second difficulty relates to the view of technology only as applied science, where science corresponds to the theoretical knowledge, while technology corresponds to the application of this knowledge. This is demonstrated in the following statements of two students: *'Science is more important than technology. Technology usually needs science'*; *'Scientists will try to think of a solution to a problem and technologists will try to put this solution into practice and construct the solution of the problem.'*

All difficulties identified and their corresponding frequencies before and after the enactment are presented in Table 3. The frequencies report how many of the interviewees were identified to face each difficulty through their interview responses.

Comparing the frequencies of the difficulties before and after the enactment is an additional measure for evaluating the TLS's effectiveness in promoting the LOs and therefore provides useful insights about improving the activity sequence for future use. According to the frequencies reported in Table 3, nine difficulties were identified before the enactment, seven of which, were either disappeared (D2, D4, D7, D9, D10) or appreciably reduced (D1, D3). D11 concerning the view of technology as applied science was slightly reduced after the enactment (N_{pre}=4, N_{post}=3). D8 concerning the failure of appreciating creativity as an integral part of technological research was slightly increased (N_{pre}=2, N_{post}=4).

Table 3

Difficulties that hamper students' attempts to differentiate between S&T

	Description of difficulty	Pre (N)	Post (N)
Difficulties related to the NOS			
D1	Decision making is conceived of as a practice that falls in the realm of S and it is practiced by scientists.	2	1
D2	Failure to appreciate the effort to understand natural phenomena as a worthwhile research goal in its own right, unless it has an ultimate goal to solve problems in society.	6	0
D3	Lack of understanding with respect to the role of experiment in knowledge development. Experiments only concern S and scientific research is always based on experiments.	8	1
D4	Failure of appreciating the distinction between generating scientific knowledge and drawing on scientific knowledge. The mere use of scientific knowledge is identified with the practice of S.	1	0
D5	There is a sharp distinction between the natural and the constructed world. Technological artefacts are made by humans and hence don't not fall under the realm of the laws of nature.	0	2
D6	When the research goal is a novelty –regardless if it relates to an effort for understanding or to a solution– then it is aligned with scientific research.	0	9
Difficulties related to the NOT			
D7	Confusion between using technological products and doing research in T.	1	0
D8	Failure to appreciate creativity as an integral part of technological research.	2	4
D9	Decision making is a problem solving process and hence, an example of T.	9	0
Difficulties related to the interactions between S&T			
D10	The study of nature and natural objects solely interests scientific research, while the study of artificial entities only interests technological research.	4	0
D11	View of technology only as applied science: S is the theoretical knowledge, T is the application of such knowledge.	4	3

Interestingly, after the enactment two new difficulties were identified. One of them, concerns students' weakness in conceiving technological constructs as entities that, despite being artificial, still obey the laws of the natural world (D5, N_{pre}=0, N_{post}=2). This difficulty was also identified in a previous study with students of various age groups, including elementary school students (Constantinou et al., 2010a). The other new difficulty, which was actually one of the two most frequently identified refers to the perception that when the research goal is novel –regardless if it relates to an effort for understanding or to a solution– then it is aligned with scientific research (D6, N_{pre}=0, N_{post}=9).

It is observed that the variety of the difficulties that were identified in students' written and oral responses was appreciably limited, while to new difficulties arose. This finding suggests that students' interaction with the TLS provided them with scaffolds to transcend most of their difficulties in appreciating the distinction between the central objectives of S&T. Nevertheless, this interaction seems not to be effective in particular difficulties which remained or increased and also has favored the appearance of two new difficulties. Especially in the case of D6, we infer that it was identified because in retrospect we observed that indeed the TLS inappropriately emphasized the element of novelty in the activities and discussions about science against the activities and discussions about technology.

5.3 Revisiting the TLS

The results presented respond to the scientific purpose of the study for answering the two research questions. Additionally, the results can be used to inform the technologically-natured purpose of the study for improving the efficiency of the teaching proposal with certain aspects of the TLS that did not worked effectively and need revisions before future enactments.

The TLS's efficiency in supporting students' ability to differentiate between the overarching goals of S&T as one way of distinguishing S&T, was validated through multiple indications, such the elaboration on students' scores in the two closed-ended tests, the comparison of their responses to the open-ended question, the comparison of the difficulties encountered before and after the enactment. All these indications converge to the conclusion that the learning goal of distinguishing between the main goals of S&T was effectively promoted throughout the activity TLS. For example, one of the most frequent difficulties that appeared before the enactment and suggests a clear confusion between the main goals of S&T (D2), was not found after the enactment.

Additionally, the results presented regarding the difficulties that hampered students' understanding about the distinction between the main orientations of S&T have an important influence in recognizing specific weaknesses of the TLS, which lead to the need for partial redesign of the activity sequence. Although most difficulties identified before the enactment, disappeared or decreased after the enactment, the rest of the results from the difficulties section demonstrate the need for revisions towards two directions. The first direction concerns revisiting the new difficulties that appeared as a result of students' interaction with the TLS and try to improve the activity sequence in this respect. The second direction of revisions relates to further elaborating on the difficulties that were identified before and remained after the enactment.

One of the new difficulties that was identified after the enactment concerns students' weakness in conceiving technological constructs as entities that, despite being artificial, still obey the laws of the natural world (D5). Although we cannot exclude the possibility of this difficulty's existence before the enactment, it is possible that it was created or corroborated during the activities. This inference is based on the fact that the telescope, which was the main object of their technological work, was built by themselves, while lenses, which was the main context of their scientific work was given to them as a readymade material for investigating and not constructed by them from scratch. Therefore, some students might have connected their technological work with artificially natured objects and their scientific work with natural objects. A revision can be the addition to the teaching material of information that students study during the design process concerning the development of lenses and how they are created. Additionally, during the teacher-group discussions, adding relevant examples that raise this issue during both students' scientific and technological work can help students that have this difficulty to overcome it.

The other new difficulty, which was also the most frequently identified refers to the perception that when the research goal is novel –regardless if it relates to an effort for understanding or to a solution– then it is aligned with scientific research (D6). The appearance of this difficulty coexisted with epistemically informed conceptions about the central goals of S&T, therefore it is inferred that it resulted because the element of novelty was more obvious and was discussed in teacher-group discussions during the generalization of the main goal and process of science. Therefore, this point in future enactments need to be more balanced for the discussions for both fields, so that it is not considered by students as a characteristic only of science.

Another difficulty, which was identified before the enactment and was found to be more prevalent after the enactment of the TLS is students' failure to appreciate creativity as an integral part of technological research (D8). This difficulty is possibly due to the fact that the teaching transformation for simulating the invention process of the telescope on behalf of the students was not so authentic, since students had to study information for certain possible solutions, but their choice was simple and easy to be made. If the scenario was more complex with more specifications or if students needed to invent something really new that was not in their existing options, then maybe this would contribute in appreciating both the novelty and the creativity of the technological endeavor. Another weakness of the TLS, which might explain the increase in the prevalence of D8 is that all groups chose the same solution through identical processes. Although each group extensively discussed its choice about building a telescope and why not any of the rest of the magnifying objects that were suggested, still it would be more helpful if the scenario "allowed" the groups to decide on a variety of solutions and also to devote time in actually improving their telescope and not merely suggesting changes for improving its function.

Another suggestion for further scaffolding students to develop their understanding that would simultaneously help in overcoming their difficulties, is the addition of an introductory unit. This unit could include activities for familiarizing students with topics such as recognizing the goal of a research project, the meaning of natural world, the fact that research projects try to respond in cases where no ready answers or solutions exist in issues that concern particular social groups in a particular space-time framework.

6. Discussion and Conclusion

Overall, the results of the study suggest through multiple indications that the TLS designed and enacted in the present research helped upper-elementary school students to improve their awareness about how S&T differ in a NOS/NOT informed manner. In addition, the results reveal difficulties that confuse students and hamper their ability to distinguish between S&T. From this evaluation, it appears that the TLS scaffolds students to overcome most of these difficulties, while the results also reveal certain needs for revisions that need to take place before future enactments, as described in the previous subsection.

At this point we need to reflect on why the TLS led to improved learning outcomes. We consider that the specification of the learning goals and the structure of the activity sequence helps students that are largely confusing S&T to elucidate their understanding. We suggest a novel combination of inquiry-oriented and design-based learning integrated with explicit epistemological discourse, where students reflect on their own activities.

Firstly, students are involved in a project that faces them with an authentic problem with a clear goal of inventing a solution to the problem. They are supported to carry out their mission and right after that, they are provided with scaffolds to reflect on their goal and actions. After discussing and visualizing main characteristics of the process they followed and their goal, they are given various similar and different projects and asked to compare them with their own, so as to further reflect and also generalize the goal into what is later labeled as the main goal of technology, that is enacted through a process called design.

Secondly, students are given another mission, which they reach through a different process. Following similar scaffolding applied for the first project (visualizing, reflection, examples for generalization), they conclude to the goal of the second project into the main goal of science that is reached in many cases through processes of investigation.

In a third stage, provided that at this point students have personal experiences of S&T, the TLS confronts them in comparing the two fields and extracting the overarching goals and processes as main distinguishing characteristics of S&T. At this point, students are in a position to elaborate on issues that relate to how S&T interrelate and how one field contributes to the other. Through a number of examples taken from the history of the telescope, students are called to recognize relevant individual scientific and technological goals and study cases were enacting a science project helped the enactment of a technology project and vice versa.

We consider that the main innovative element that resulted in positive learning gains was the certain combination of inquiry-oriented and design-based activities that integrated explicitly epistemological discourse, which guided students to develop their awareness of the interrelationship between S&T. The continuous matching of various activities to the LOs is also thought as scaffold throughout the development of this TLS.

Such results provide empirical support to the claim made in the research literature that young learners can develop their NOS understanding through purposefully designed inquiry-oriented activity sequences that enhance EED (Clough, 2006; Lederman, 2007; Sandoval, 2003). Consequently, given that NOS/NOT issues such as understanding the interrelationship between S&T are valued as substantial learning goals, then purposefully planned group discourse activities need to draw students' attention to features of both S&T in ways that highlight their fundamental differences and also their interdependencies.

The contribution of the study is that it adds to the limited number of attempts at developing similar TLS, especially in elementary education and the absence of similar published research attempts for the case of teaching about the interrelationship between S&T in elementary school students. Within this respect, the study provides promising indications about the appropriateness of promoting such LOs through specially designed learning environments that incorporate authentic practice of inquiry and design integrated with EED activities. Additionally, the study provides further empirical support to the claim made in the research literature concerning upper-elementary school students' readiness in engaging in epistemological discourse and developing NOS/NOT awareness (Lederman, 2007). Finally, this study partially contributes to the validation of a TLS with respect to its ability to promote awareness about the distinction between the overarching goals of S&T as a prerequisite for exploring connections between the two domains. At this stage the promising results and the available data are currently under consideration for the revision of the TLS so as to further enhance its effectiveness with respect to the LO that it addresses.

CHAPTER IV

Electromagnetic properties of materials as a context for teaching aspects of the interrelationship between science and technology: explicit or implicit approach?

Abstract

This study investigates the potential impact of EED in improving student understanding of the interrelationship between S&T through a combined inquiry-oriented and design-oriented teaching and learning activity sequence on Electromagnetic Properties of Materials. We implemented two conditions of the activity sequence; one included EED activities on the interrelationship between S&T, the other condition included identical inquiry and design activities, with additional practice exercises substituting the reflection activities on EED. The participants were 16 year-old students from intact classes (N=37 and N=26, respectively). Pre-post tests and interviews evaluated students' understanding about the goals of S&T. Students in the EED condition with no extra choices in science school subjects surpassed students in the non-EED condition who had chosen specialized elective courses in high school physics. The results support that students' awareness about the interrelationship between S&T is improved when integrating EED into classroom activities that are credibly authentic and relevant from the students' perspective. We discuss the role of reflection activities in science education and present implications of our findings for future research towards better integration of epistemological reflection in science classes.

Keywords

nature of science and technology, explicit epistemological discourse

1. Introduction

The NOS and the NOT have long been considered core learning objectives and fundamental components of scientific and technological literacy (AAAS, 1989; Driver, Leach, Millar & Scot, 1996; ITEA, 2007; Kang, Scharmann & Noh., 2005; Lederman, 2007; McComas & Olson, 2002; NRC, 1996, 2000, 2007; Taber, 2008 among many others). Additionally, there is widespread recognition that more research is needed to better understand relevant parameters to teaching and learning about NOS and NOT and also to develop teaching innovations that scaffold student and teacher efforts in this endeavor (Lederman, 2007; Sandoval & Morrison, 2003), especially in the lower school grades (Akerson & Volrich 2006; Kang et al., 2005). This study addresses this need by focusing on the interrelationship between S&T, which is recognized as one aspect of the NOS/NOT that should be advanced through S&T education (Constantinou et al., 2010a; Hadjilouca et al., 2011; McComas, 2008) and has not been adequately studied thus far (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

A challenging issue with direct implications on the design of teaching innovations concerns the role of explicitness as a pedagogical strategy when integrating NOS/NOT issues in classroom activities. Both implicit and explicit approaches have been reported (Schwartz, Lederman, & Crawford, 2004). *Implicit approaches* rely on the premise that providing students with rich experiences spontaneously leads students to fruitful reflections on the NOS/NOT and consequent appreciations of important aspects of these constructs. *Explicit approaches* deem that students' attention to epistemological issues needs to be explicitly targeted through purposefully planned group discourse activities (Oliveira, Akerson, Colak, Pongsanon, & Genel, 2012; Schwartz, et al., 2004).

Prior research on investigating explicitness in NOS/NOT teaching examined the role of systematically engaging students in reflective and structured discussions. Relevant literature suggests that embedding such EED improves NOS understanding (Clough, 2006; Lederman, 2007; McComas, 2002; Sandoval, 2003). However, this approach was not extensively investigated with NOT nor was it ever been examined with respect to the interrelationship between S&T.

Inquiry-based and design-based teaching and learning are established paradigms in S&T education. The inquiry-based teaching and learning framework seeks to enhance the authenticity of school science, while at the same time placing emphasis on conceptual change and the emergence of coherent conceptual frameworks (NRC, 2012; Kyza et al., 2011). Design-based teaching and learning facilitates active learning and engages students in problem solving processes with explicit reference to meeting life's challenges and social priorities (ITEA, 2007). It involves the methodical design and often the construction of artifacts followed by an evaluation of the extent to which the end product or process meets pre-defined specifications (Bybee, 2011; ITEA, 2007). This study is part of a broader project, that studies how the combination of inquiry-based and design-based teaching could provide a rich context for learning about differences and connections between S&T, therefore contributing in raising students' awareness of the NOS and the NOT. More specifically, this study focuses on investigating the influence of EED on students' awareness about the difference between the overarching goals of S&T through a TLS. The study addresses the following research questions:

(1) To what extent does extensive interaction with inquiry-based and design-based activities *(Non-EED condition)* improve upper-secondary school students' awareness about the difference between the overarching goals of S&T?

(2) To what extent does the integration of EED activities *(EED condition)* in a TLS that combines inquiry-based and design-based activities improve upper-secondary school students' awareness about the difference between the overarching goals of S&T?

2. Background

2.1 Teaching/learning about the NOS/NOT

Our theoretical assumptions derive from two dimensions that preoccupy ongoing research about teaching/learning NOS/NOT: a. *How* should NOS and NOT be taught? b. *What* should be taught about NOS and NOT?

2.1.1 Strategies for teaching NOS/NOT. Two important issues: Explicitness and context.

Explicit or implicit approach in the development of informed conceptions of NOS/NOT? Engaging students' in EED is suggested as a critical factor that facilitates NOS understanding, i.e., there is value in approaching NOS as a learning objective and consequently plan teaching in ways that explicitly draw students' attention towards NOS issues (Clough, 2006; Khishfe & Ab-El-Khalick, 2002; Lederman, 2007; McComas, 2002; Sandoval & Morrison, 2003). This claim is supported by empirical evidence stemming from two main research lines.

The first is concerned with the learning gains that are reported in studies of teaching aspects of the NOS (other than the interrelationship between S&T) through systematically engaging students in EED (Akerson & Donnelly, 2010; Akerson & Volrich, 2006; Bell, Matkins & Gansneder, 2011; Carey, Evans, Honda, Jay, & Unger, 1989; Khishfe & Abd-El-

Khalick, 2002; Khishfe & Lederman, 2006; Peters, 2012). We would note here that only three of these studies report direct comparisons between implicit and explicit approaches, one with sixth graders (Khisfhe & Abd-El-Khalick, 2002), one with eighth graders (Peters, 2012) and one with preservice elementary teachers (Bell et al., 2011). While all three studies report findings supporting the explicit approach, more extensive research for comparing the relative effectiveness of the two approaches is needed, especially in upper-secondary education where no published study was found thus far on any NOS aspect.

The second category refers to studies that investigated the possibility of emergent NOS awareness through rich experiences of science learning. These studies can be further classified into two subcategories. The first refers to intervention studies reporting efforts to pursue learning objectives directly related to NOS, but without treating them in an explicit manner. Underlying such implicit approaches is the assumption that understanding of the NOS could emerge as a by-product of students' engagement in inquiry-oriented learning activities. However, findings from assessments of students' learning outcomes fail to corroborate this assumption considering their deficiency to reveal significant learning gains on NOS aspects (Abd-El-Khalick & Lederman, 2000a; Khishfe & Abd-El-Khalick, 2002; Lederman, 1992; Moss, Abrams, & Robb, 2001; Sandoval, 2003, 2005; Sandoval & Morrison, 2003). The second subcategory comprises studies that sought to evaluate students' awareness of various NOS aspects. One of these aims at evaluating elementary, secondary and preservice elementary education students' awareness of the interrelationship between S&T and specifically their appreciation of the distinction between the orientations of S&T (Constantinou et al., 2010a). These studies demonstrate that students' awareness does not improve with age or with the sustained exposition to conventional science teaching (Abd-El-Khalick, 2006; Constantinou et al., 2010a; Kang et al., 2005). Coupled with the fact that conventional science teaching often adopts other priorities than to explicitly address learning objectives relevant to the NOS (e.g. conceptual understanding), this highlights the interest in investigating the potential value of engaging students in EED.

Integrated (contextualized) or non-integrated (decontextualized) approach in the development of informed conceptions of NOS/NOT? Research literature provides useful insights into possible ways of advancing improved understandings of NOS/NOT in science teaching and learning regarding the extent and type of integration with other aspects of science learning. Specifically, three approaches are suggested: (a) *Nonintegrated (de-contextualized) activities* wherein the elaboration about the NOS is disconnected from the science topic under study (e.g., Lederman & Abd-El-Khalick, 2000; Bell, 2008; among others); (b) *Integrated (contextualized) activities* that seek to embed epistemological aspects of science in the same activities that are intended to elaborate the conceptual aspects of the context under study (e.g., Khishfe & Lederman, 2006; Walker & Zeidler, 2003; Zeidler, Walker, Ackett, & Simmons, 2002); (c) *Studying episodes drawn from the history of science* with a view to abstract epistemological ideas (e.g., Abd-El-Khalick & Lederman, 2000a; Clough, 2011; Kim & Irving, 2010; Olson, Clough, Bruxvoort, & Vanderlinden, 2005; Rudge & Howe, 2009; Solomon, Duveen, Scot, & McCarthy, 1992; Straits & Nichols, 2007; Yip, 2006).

Further research is needed on the relevant effectiveness of these approaches. Only three comparative studies have been reported so far, comparing integrated and non-integrated approaches (Bell et al., 2011; Khishfe & Lederman, 2006, 2007). The results of these three studies do not clearly favor a single approach, since moderate improvements in students' NOS awareness were found in all types. We have been unable to identify any studies that compare the effectiveness of promoting NOS understandings through stories from the history of science and the use of the integrated or the nonintegrated approach. Our study is aligned with the integrated approach.

2.1.2 Content of NOS teaching

The appropriateness of promoting students' awareness of the NOS as a learning objective has been questioned in view of the lack of philosophical consensus on a single account of how science operates (Alters, 1997). This position relies on the premise that it is not reasonable to expect students to become knowledgeable about the NOS, given that not even philosophers of science do not fully agree on how to best represent the NOS. However, there is consensus within the science education community that whatever the scientific content students are intended to gain (e.g., conceptual understanding, NOS understanding, reasoning skills, practical skills, experiences, attitudes), it should be appropriately transformed toward meeting students' needs and use their ideas as a starting point. Consequently, transformations are bound to include justified simplifications of the scientific content that align the complexity of the targeted ideas with students' cognitive readiness.

One challenge that is inherent in attempts to devise teaching transformations for the NOS, is how to avoid conflicts with corresponding ideas that are widely accepted within the philosophy of science. Despite being simplified and incomplete, the ideas that students are intended to develop should serve a productive role and should be amenable to elaboration at subsequent stages so as to become increasingly sophisticated and epistemologically coherent (Taber, 2008). From this perspective, disagreements among philosophers of science are not always relevant to school science (Lederman, 2007; Smith, Lederman, Bell, McComas, &

Clough, 1997), in that science teaching merely aims at helping students develop fundamental consensus ideas of how science works while excluding the intricacies of the underlying (philosophical) discourse. This rationale corresponds to the consensus perspective used by several science education researchers (Abd-El-Khalick, Bell & Lederman, 1998; Lederman, 2007; McComas, 2008; Osborne et al., 2003). The interrelationship between S&T, which is the focus of the present study, is one idea that is part of this consensus view (McComas, 2008; Osborne et al., 2003).

2.2 Teaching and learning about the interrelationship between S&T

2.2.1 Core differences relevant to science education

S&T are two highly interacting fields of social activity. Nevertheless, they are considered as distinct domains. A fundamental difference between S&T, which is the focal point of the intervention in this study, relates to orientation, the overarching goal each field pursues: Science seeks to generate reliable knowledge; technology seeks to respond to human needs by developing solutions to problems (AAAS, 1989; Agassi, 1980; Arageorgis & Baltas, 1989; Constantinou et al., 2010a; Bybee, 2011; Custer, 1995; Gardner, 1993, 1994a; ITEA, 2007; Jones, 2006; NRC, 1996). From a methodological viewpoint, another distinction refers to core processes adopted for achieving the different goals of S&T. Specifically, controlled experimentation or, more broadly, investigation is a core process in science, while design is a core process in technology (De Vries, 2009; Jones & Buntting, 2015; Lewis, 2006; NRC, 1996, 2012; Constantinou et al., 2010a).

Controlled experimentation[19] is a specific methodology employed in scientific research with the objective "to test hypothesized links of causation or functional relationships, that is, tentative explanations" (Gyllenpalm & Wickman, 2011, p.4). This methodology could be implemented when studying causal relationships between variables that might be involved in a phenomenon. It includes the performance of a specific planned change in a system and the study of its effects, while simultaneously as many extraneous variables as possible are kept constant (Beveridge, 1961; Böck, 2001). Controlled experimentation can be thought of as one approach to scientific investigation. An understanding of controlled experimentation combines both conceptual and procedural aspects, which are important facets of scientific thinking (Duggan & Gott, 1995).

In this simplified transformation, the methodological aspects of technology can be described by the construct of design. Design rests on a set of attributes that can be iteratively

[19] Also reported as *control of variables strategy* (D. Klahr, D. Kuhn), *design and conduct of scientific investigations* (D. Kuhn, N. Lederman), *experimental design* (N. Lederman).

combined to devise a solution to a problem, that corresponds to an end product or a process, satisfying certain specifications. Such attributes include the following: Definition and representation of the problem, formulation of specifications, search for relevant information, brainstorming of ideas and planning, selection of the best idea, development of a model of the selected solution, test and evaluation of the model of a solution, refinement, usability test, communication of results (ITEA, 2007).

It is important to recognize that the processes employed in S&T are much more complex and obviously not restrained exclusively to controlled experimentation or design, respectively. Nevertheless these two processes are core representative features of the two domains and therefore could serve as starting points for teaching about the distinction between S&T (Hadjilouca et al., 2011).

2.2.2 Connections

Developing awareness about the interrelationship between S&T posits an interesting challenge for S&T education, given the complex nature of both enterprises, their interconnections and mutual influences. For the purposes of school teaching/learning, the following simplified account provides a structure for rich and fruitful development: S&T constitute two closely linked areas of human activity, which are strongly interdependent, providing a scientific underpinning to modern technological processes and a technological underpinning to modern scientific processes. Specifically, science contributes to the development of technology through (a) providing background knowledge (theories/laws/models) that inform and often guide the design of technological innovations, and (b) posing challenges (to be seized by technology) regarding the design of novel processes or instrumentation (i.e., the instruments/procedures for measuring/monitoring/controlling). Respectively, technology contributes to the development of science by (a) facilitating experimentation, through the provision of more reliable and accurate methods and instruments and (b) generating new research questions for scientific inquiry.

The TLS we enacted for promoting secondary school students' awareness of the interrelationship between S&T places emphasis on these dual ideas: mutual support and interacting requirements between S&T.

2.2.3 Why is the interrelationship between S&T an important NOS/NOT objective?

Realising the potentials and constraints of these two domains of human activity is important for developing an ability to effectively engage with socio-scientific issues (Sadler, 2004;

Zeidler, Sadler, Simmons, & Howes, 2005), which is recognized as another important component of both scientific and technological literacy (AAAS, 1989; ITEA, 2007, 2003; Jones, 2006; Kolstø, 2001, 2008; Sandoval, 2005). New knowledge in this area could inform and facilitate attempts to devise mechanisms for increasing students' interest towards S&T courses (Gago et al., 2004; NSB, 2003; OECD, 2006; Roberts, 2002) and it could offer guidance on future careers (Jones & Buntting, 2015). More specifically, it could help the education system to encourage students to make more informed decisions and this could, in turn, increase the likelihood for successful career choices and advance responsible citizenship (Hazelkorn et al., 2015; Jones & Buntting, 2015).

The prevalent conceptions about S&T are important for efforts to communicate publicly their role in society and the outcomes of the various policy procedures for developing research funding priorities. For instance, the level of public support for an innovation system in close symbiosis but distinct from the science system, and also closely related with financial investment mechanisms, is directly related to the level of public understanding of the differences between S&T and the diverse roles they play in economic development.

Possessing informed views about the interrelationship between S&T is recognized as an important NOS/NOT aspect for all these reasons. However, this aspect has not been adequately studied thus far, especially in the case of secondary school students (Akerson & Volrich, 2006; Kang et al., 2005).

3. Method

3.1 Participants and school settings

We implemented two versions of the TLS with two intact groups of 16 years old students. The first implementation takes place in a S&T summer school (N=26), while the second takes place in a public high school (N=37). Each implementation lasts twenty 80-minute sessions with the participation of the same three experienced physics teachers in each case. Both implementations include the same combination of inquiry-based and design-based activities. The difference between the two implementations is the presence of EED in the second implementation. Specifically, the second implementation follows an explicit approach that includes EED activities regarding the interrelationship (i.e., differences and connections) between S&T, while the first implementation (non-EED) follows an implicit approach that includes more practice exercises substituting the reflection EED activities.

3.2 Teaching approach and learning materials

3.2.1 Prior development of the TLS

For this study, we chose a mature and tested TLS which had been implemented and refined through a series of six iterative design cycles. It focuses on Electromagnetic Properties of Materials. It was designed by a workgroup comprising science education researchers, materials science researchers and experienced teachers. The design rationale of the TLS draws on the combination of inquiry and design activities to promote complex learning that includes conceptual understanding, technological design skills and knowledge, and appreciation of aspects of the NOS as elucidated by Constantinou et al. (2010b, 2010c).

The TLS elaborates an authentic scenario by engaging students in the design, implementation and evaluation of learning artifacts (Constantinou et al., 2010b, 2010c) and is organized into two main units. The first unit involves inquiry-based activities where students are extensively engaged in exploring magnetic and electromagnetic phenomena through: making and interpreting observations, developing and refining conceptual models (force at a distance-field, magnetic domains), designing and conducting investigations. The second unit engages students in a technological design process in which they construct and evaluate electromagnetic train models. In their designs, they need to propose mechanisms for train levitation and propulsion, along passenger protection from electromagnetic radiation. The EED version of the module integrates — additionally to the non-EED version — specially designed activities for explicitly engaging students in epistemological discourse about distinctions and connections between S&T. The overall teaching time is kept constant by removing redundant inquiry activities (thereby reducing the time spent on gaining practice in applying learnt concepts) and the time available for designing and constructing the train model by a total of 10%.

3.2.2 Epistemologically oriented LOs

We investigate the hypothesis that the combination of inquiry and design activities provide a rich context for advancing the following LOs: Students, (a) develop awareness of the distinction between the different overarching goals of S&T (producing reliable knowledge about natural phenomena vs developing solutions to respond to human problems and needs), (b) develop awareness of the difference in the core methodological frameworks that are commonly adopted by S&T (investigation and design, respectively), (c) identify aspects of the contribution of S to the development of T (S provides the knowledge base for the development/improvement of technological equipment and also science formulates questions that necessitate new instrumentation, i.e., the invention of specialized instruments/processes for measuring, monitoring or controlling), and (d) identify aspects of the contribution of T to the development of S (T facilitates the conduct of experiments by providing instruments and experimental techniques and also new technologies tend to initiate scientific research by revealing new questions concerning the phenomena and mechanisms underlying the operation of these technologies). Assessment focused on the first LO, namely student awareness of the distinction between the different overarching goals of S&T.

3.2.3 General overview of the activity sequence

Implicit approach (non-EED TLS). The first version of the TLS does not include any reflective EED activities concerning the interrelationship between S&T. It includes inquiry-based activities that extensively engage students in investigating magnetic and electromagnetic phenomena through activities that include the following: Data collection and analysis regarding magnetic interactions and magnetic fields, developing and refining a conceptual model for magnetic materials, carrying out controlled experiments to investigate variables that influence the interaction between electromagnets and ferromagnetic objects. It also includes design-based activities that engage students in a process of designing, constructing and evaluating a magnetic levitation train.

During the "scientific inquiry" phase of the TLS, students repeatedly use technological apparatus (e.g., sensors for measuring the intensity of magnetic fields, a simulation for observing the earth's magnetic field) or construct their own objects (e.g., construct electromagnets to investigate how different variables might influence their interaction with ferromagnetic objects). Correspondingly during their "technological work", students explicitly revisit scientific knowledge previously obtained (e.g., variables that influence the attraction between electromagnets and ferromagnetic materials) or carry out small-scale scientific work with the purpose of helping them construct the magnetic levitation train (e.g., what influences the polarity of an electromagnet, what materials provide better electromagnetic screening). In this sense, students gain first-hand experience with the potential interactions between S&T. The material of the TLS is available upon request through Constantinou et al. (2010b).

Explicit approach (TLS with EED). The second version of the teaching-learning sequence is bounded with activities that engage students in reflective and structured group discussions with respect to elaborating on some of the distinctions and connections between S&T according to the learning goals. An overview of how these activities embed such EED follows:

(a) While introducing the magnetic field as a concept that accounts for interactions at a distance and while constructing the domains model of magnetic materials, the goal of science is discussed through structured questions in an attempt to connect the introduction of such concepts and models with the goal of science to interpret and predict natural phenomena.

(b) After carrying out structured investigations to examine how different variables might influence the attraction between electromagnets and ferromagnetic objects, students are guided to reflect on the process of investigation that was followed and ponder why this process may serve the goal of science in producing reliable knowledge about natural phenomena.

(c) At the beginning of the design process, after the problem is presented, students discuss whether trying to respond to a local transport problem by developing a magnetic levitation train is more aligned to the goal of science or technology, and why, as a society, we value reliable knowledge as a resource for solving problems.

(d) During the design process, students are given short descriptions of various examples of research goals and various research processes and they are guided to abstract from their own activities and generalize by identifying similar situations where the need for investigation or design might arise.

(e) A last part of the TLS asks students to think of their own examples of scientific and technological goals and processes and relate them to their own experiences throughout the TLS and, in each case, think whether S&T respectively helped them in achieving each goal. Additionally, they study two narratives of other research programs that depict examples of interaction between S&T and they are asked to identify instances where technology might contribute to science and vice versa.

3.3 Educational setting constraints

The participants of each condition, although at the same age level and exposed to the same overall teaching time do not share common characteristics in certain respects. Specifically, participants in the *non-EED condition* were self-selected to participate in a S&T summer school and had higher elective school courses comparing to the average interest in physics of students and also had chosen to take more physics-oriented lessons than usual. Participants in the *EED condition* were studying in a public school and the enactment was carried out as part of their mandatory physics course and had no extra science-oriented major lessons in the current or previous high school years. Nevertheless, these disparities between the two groups do not controvert the validity of the research design for two reasons. Firstly, prior research on students' conceptions of NOS/NOT in general and the interrelationship between S&T in particular, suggests that students do not typically possess informed conceptions (Constantinou et al., 2010a), therefore differences between the two groups' prior knowledge on this theme were not typically expected. This expectation was retrospectively corroborated through independent samples t-test comparison between students' scores in two pre-tests (FT and ED tests, which are explained next) where we found no statistically significant differences between the two groups' scores ($t_{FTtest}(62)=6.45$, $p>0.05$; t_{ADtest} $(62)=7.1$, $p>0.05$).

Secondly, the study is interested in possible differences between students' initial and final conceptions in each group, and not on actual horizontal differences between the final conceptions of each group. We clarify that to answer the second research question we use the results of the first research question, i.e., the *non-EED* group served as a control group and the corresponding differences between the *EED* group's initial and final conceptions were compared between the two conditions.

3.4 Data sources and data analysis

Prior to and after the enactments of the two versions of the TLS we collected data to assess students' awareness of the distinction between the different overarching goals of S&T for potential learning gains and, thereby, derive a preliminary measure for the potential effectiveness of the TLS when adopting an implicit (non-EED) or explicit (EED) approach in addressing this aspect of NOS/NOT.

The assessment involves the combined use of two tests that were developed in a previous study (Constantinou et al., 2010a)[20]. The two tests, are designed so that their items work in parallel and they are administered sequentially in one session. Each of these tests consists of the same 18 multiple choice items, with each item describing the main objective of a certain research project in contexts unrelated to the ones that students study as part of the TLS: science (e.g., We examine whether microwave ovens are dangerous for our health and also what sort of problems they might cause), technology (e.g., We try to make filters to absorb polluting fumes that are emitted from factory chimneys) or neither of these two (e.g., We are trying to decide the best location to build a desalination plant). Students are asked to categorize these descriptions using a given criterion. In the first test (Formal Terminology, FT), students are asked to determine whether the stated objective of each project was more

[20] We removed some items that were found in previous studies as the easier ones, for the purpose of saving time. This shortened version can be found in Appendix C.

closely aligned with the goal of science, technology or neither. In the second test (Elaborated Definitions, ED), students are asked to differentiate between projects whose objective either involves the improvement of our understanding with respect to the behavior of some aspects of the natural or built world, or involves the development of solutions to problems encountered by society, or involves a different goal, unrelated to the previous two. The ED test assesses whether students respond with consistent effort, based on what they read, without resorting to random answers. Noticeably, the two sets of criteria in the two tests are epistemologically equivalent in that the second set (ED test) draws on the core objectives of S&T. Underpinning the combined use of FT and ED tests is the idea that students who are able to differentiate between S&T in terms of their overarching objectives, would respond to both tests in a similar manner. Thus, the correlation of students' responses to the two tests assesses their awareness of this topic and, hence, provides a measure of their awareness of the distinction between S&T (Constantinou et al., 2010a). Additionally, Wilcoxon tests on students' performance in the pre- and post- tests are used to identify possible statistical differences in students' performance prior to and after the enactments. In addition to the multiple-choice items, at the end of the FT test and prior to the administration of the ED test, an open-ended question is included, which asks students to explain how they would determine whether a given research project seems either technologically or scientifically oriented. This information is used for triangulation purposes (Constantinou et al., 2010a).

Students' responses to the open-ended task are categorized in qualitatively different levels of distinguishing between S&T. Existing categories from a previous study (Constantinou et al., 2010a) that resulted from phenomenography (Marton & Booth, 1997), are initially adopted and next slightly adapted so as to better describe the data of the present research. The initial categories used from Constantinou et al. (2010a) had resulted from a careful study of the students' responses with the explicit purpose to identify and describe each underlying reasoning. This process had led to the identification of the qualitatively different ways of distinguishing between the two fields.

Follow-up semi-structured interviews[21] with 30% of the participants, were intended to help us describe students' reasoning and interpret possible conceptual or epistemological difficulties hampering their learning pathways. Each interviewee was asked to respond (for a second time) to a selected sample of items included in the two tests and next explain his/her reasoning. Additionally, whenever the interviewer identified inconsistencies (e.g., cases in which interviewees provided incompatible responses to the various items or responded

[21] See Appendix D for the interview protocol.

differently as compared to the written test), she explicitly confronted students with these discrepancies and asked them to elaborate on them. These interviews are intended to provide a more detailed account of the reasoning underlying the student responses. This is also anticipated to inform our interpretation of data from the open-ended question of the FT test, in which students are explicitly asked to explain their reasoning (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

3.5 Reliability and content validity issues

The two tests assessing students' awareness of the distinction between the overarching goals of S&T were adopted from a previous study in which they were exposed to various procedures intended to ensure their content validity and reliability (see Constantinou et al., 2010a).

4. Results

All results are tabulated in Tables 1 and 2 and described in the next two subsections.

4.1 Research question 1: To what extent does extensive interaction with inquiry-based and design-based activities (non-EED condition) improve upper-secondary school students' awareness about the difference between the overarching goals of S&T?

The question was answered through various measures from the students who participated in the non-EED condition. Firstly, the students' mean scores to the multiple-choice task of the FT test: 59% prior to and 63% after the implementation. Secondly, the Wilcoxon test did not yield statistically significant changes in the students' performance in either of the two instruments: $FT_{pre\text{-}post}$ (z=1.98, p>0.05) and $ED_{pre\text{-}post}$ (z=–1.05, p>0.05). These suggest a lack of change in these students' awareness of the distinction between the overarching goals of S&T. The negative and non-significant z value in $ED_{pre\text{-}post}$ performance implies that students' performance did not improve after the intervention. Additionally, given that the two tests are conceptually identical, as explained in Section 3.4, it was hypothesized that, had the students appreciated the distinction between the different goals of S&T, they would answer the two tests (FT and ED) in a similar manner and thus the correlation analysis would have yielded high coefficients. However, this was not verified; in contrast, the correlation coefficient decreased by 20%, after the intervention: $R_{FT\text{-}ED}$=0.55 (p<0.05) prior to and $R_{FT\text{-}ED}$=0.45 (p<0.05) after the implementation. This decrease in the correlation coefficient suggests that after the intervention some students answered the questionnaires randomly. All three indications as shown in Table 4 in the *non-EED* row, suggest a lack of improvement in students' awareness of the distinction between the goals of S&T in the *non-EED* implementation.

Table 4

Results from the FT and the ED* tests*

	Test	Time	No-EED group	EED group
(1) Scores, *% in*	FT	pre *(sd)*	59 *(2.39)*	52 *(2.15)*
		post *(sd)*	63 *(2.19)*	62 *(2.93)*
	ED	pre *(sd)*	*73 (2.81)*	61 *(2.77)*
		post *(sd)*	69 *(3.12)*	74 *(2.47)*
(2) Wilcoxon test, z *between*	FT	pre-post *(p)*	1,98 *(0.12)*	3.60 *(0.00)***
	ED	pre-post *(p)*	–1.05 *(0.23)*	4.60 *(0.00)***
(3) Correlation, r *between*	FT–ED	pre *(p)*	0.55 *(0.00)***	0.43 *(0.00)***
	FT–ED	post *(p)*	0.45 *(0.02)*	0.64 *(0.00)***

* FT: Formal Terminology, ED: Elaborated Definitions
** Reject the null hypothesis at $p<0.01$

Similar indications result from students' responses to the open-ended item. Six qualitatively different categories of distinction between S&T were formulated as shown in Table 5 with examples of typical student responses. Epistemologically informed responses fall into the first category, where the distinction refers to the different goals pursued by the two domains.

Responses in the remaining five categories deviate from epistemologically informed conceptions and corroborate conceptions found previously in an extensive investigation of students' understanding of this issue (Constantinou et al., 2010a).

Responses in the second category discriminate between S&T based on the methods appeared in each domain (e.g., experimentation and construction of artefacts in S&T, respectively) lacking epistemological justification, but rather influenced by conventional teaching practices in S&T lessons. Students' responses did not reflect the distinction between S&T in terms of processes (i.e., investigation as core process in science, design as core process in technology). Instead, students were more influenced by their experience in conventional teaching practice in S&T, in line with current curricular priorities in this setting, which often emphasize these specific processes (experimentation, construction work) without explicit connections to the epistemological underpinnings of S&T. These types of superficial ideas were also reported by previous research (Constantinou et al, 2010a;

Gardner, 1999; Gil-Perez et al., 2005) with one of the most indicative being reflected in the following interview excerpt:

> *Student 11, EED condition, interview prior to the intervention*
> Student: It's science when we do experiments. In earlier grades when we did experiments it was in order to prove something through science. The other statement refers to technology because technology discovered computers and through computers we can search to find information and get results.
> Interviewer: So, are you saying that the actual using of technology is the main goal of technology?
> Student: Yes.

Responses in the third category reflect discriminations based on objects of study in each domain. These responses distinguish between S&T by placing emphasis on a perceived dichotomy between natural Vs constructed objects of interest, regardless of the specific aim of the project. Students in this category depart from the premise that science relates to the natural world and technology relates to human-made artefacts. Based on this premise, they seem to draw the false inferences that no scientific work can be done with constructed objects or processes as the main object of interest and also that no situations can be conceived where it might be possible to have technological intervention on natural processes or natural objects. As further investigated through the follow-up interviews, such student statements fail to perceive the overlap between the natural world and human products, as objects of study or intervention sometimes by science and other times by technology. By applying this overarching *Natural Vs Artificial* criterion, students are led to a variety of intriguing ideas about which goals are scientific or technological. Examples follow:

> *Student 7, EED condition, interview prior to the intervention*
> Student: It is a goal of technology when they deal with technological products, e.g., microwave ovens are technological, not something scientific.
> Interviewer: So, let's take as an example the case where researchers are trying to investigate whether microwave ovens are dangerous for our health and what types of problems they might cause.
> Student: Then, it's technology.
>
> Student 9, EED condition, interview prior to the intervention
> Student: When they are constructing something useful for mankind, then it is science. When they are constructing something else, irrelevant to human life, such as an aquarium, then it's technology.

Responses in the fourth category are rather ambiguous about discriminating between S&T, while responses in the fifth category explicitly treat S&T as identical fields. The sixth category included irrelevant or no responses.

Comparing the percentages between the categories for the *non-EED* condition, no shift toward informed awareness about this issue is observed. This fourth indication is consistent with the first three indications that were obtained from the multiple-choice tasks.

4.2 Research Question 2: To what extent does the integration of EED activities (EED Condition) in a TLS that combines inquiry-based and design-based activities improve upper-secondary school students' awareness about the difference between the overarching goals of S&T?

This question was answered by comparing the results presented above for the *non-EED* condition with the corresponding results for the *EED* condition. Students' performance in the FT test prior to and after the *EED* enactment was 52% and 62%, respectively. The two groups had a different starting point in the pre-tests (59% by the non-EED group, 52% by the EED group). Interestingly, they end up with similar final scores (63% in non-EED group, 62% in EED group). In other words, students with same core physics course background (EED group) improved 2.5 times more than students with higher-level of elective courses in school physics as well as a demonstrated higher interest in physics (non-EED group). Concerning students' performance in the ED test, a 13% increase for the EED group was observed as opposed to the 4% corresponding decrease of the non-EED group. This increase for the EED group reveals that students of this group developed markedly increased awareness of the different goals of S&T, after the enactment. Wilcoxon tests also indicate this learning gain, by yielding statistically significant increases in students' performance in both tests: $FT_{PRE-POST}$ (z=3,6, p<0,05), $ED_{PRE-POST}$ (z=4,6, p<0,05).

Additionally, the correlation coefficient between students' scores in FT and ED tests presents an approximately 30% increase: $R_{FT-ED}=0.43$ ($p<0.05$) prior to and $R_{FT-ED}=0.64$ ($p<0.05$) after the enactment. This indicates students' tendency to respond to the two tests after the implementation in a more consistent manner. Namely, students respond to the two tests with more similar reasoning as compared to their own responses in the pre-tests and also the post-tests of the non-EED group, i.e., they are in a better position to differentiate between S&T with the epistemologically-informed criterion they were taught.

All these indications support that students' awareness of the distinction between the overarching goals of S&T was improved after the *EED* enactment. Concerning students' responses to the open ended item (see Table 5) prior to and after the *EED* enactment, a large shift of post-responses towards the first category is observed. This finding also suggests improvement in students' awareness of the distinction between the overarching goals of S&T in the *EED* implementation.

Table 5

Students' responses to the question 'How do you determine whether a given research project is more scientifically or technologically oriented?'

	Description of category	Typical student responses	Non-EED group pre (%)	Non-EED group post (%)	EED group pre (%)	EED group post (%)
1	Discriminating based on the goal of each domain. Science seeks to explain why something happens. Technology seeks to invent or construct something useful that solves a particular problem.	'A project belongs to science when the goal is understand how something is done. It belongs to technology when they try to find ways that improve human life.'	50	46	11	62
2	Discriminating based on the methods that appear in each domain. Reference to experiments, observations, predictions, etc. as methods used in science. Reference to construction, measurements, etc, as methods employed in technology.	'A project belongs to science when we do an experiment. A research project belongs to technology when we construct something.'	12	8	8	0
3	Discriminating based on the object of study in each domain. Science deals with the natural environment (objects not made by humans), while technology deals with the artificial environment (objects built or improved by humans).	'When it refers to nature, the research belongs to science. But when it relates to inventions made by people, then it belongs to technology.'	0	19	43	14
4	Inadequate or ambiguous discrimination.	'In science we study things. In technology people make things.'	15	15	16	8
5	No difference mentioned and the two domains are attributed with the same identity.	'There is no difference. Science and Technology are two parts of the same activity.'	15	12	0	5
6	Irrelevant answers (do not respond to the question, tautologies) or no response.	'In science we do scientific stuff and in technology we do technological stuff.'	8	0	22	11

5. Discussion

5.1 Teaching implications

Reflecting on the results of the study we need to discuss the role of EED in achieving traceable learning gains on NOS/NOT issues. Existing relevant research identifies the need to investigate the issue of explicitness in NOS/NOT teaching by examining the role of systematically engaging students in structured reflective discussions. Literature already proposes that embedding such EED improves NOS understandings (Clough, 2006; Lederman, 2007; McComas, 2002; Sandoval, 2003). Results in this study extend these findings and additionally, highlight the need for further elaboration on how to embed EED in science classes and especially on the importance of planning for reflective activities. Our findings confirm that doing S&T is not a sufficient condition that spontaneously leads upper-secondary students to epistemological reflections related to NOS/NOT. Students enter S&T lessons with alternative intentions (just like they enter the classroom with alternative conceptions of scientific concepts). These intentions are alternative in the sense that they diverge from the learning objectives. Therefore, by guiding them in doing S&T, it cannot be assumed that they would spontaneously reflect on issues related to NOS/NOT. Consequently, if these are valued as substantial learning goals, then purposefully planned group discourse activities need to draw students' attention to features of both S&T in ways that highlight their fundamental differences and also their interdependencies.

Interestingly and not irrelevantly, this issue is consistently connected with the history of science and is reported as the mismatch between what scientists do and what they state they did when they communicate their findings in publications (Schickore, 2008). In the history of science, we see scientists not merely striving to produce new knowledge but having other various (scientifically divergent) motives for enacting and elaborating on their research, such as personal or community interests, religious or cultural beliefs (Szumilewicz, 1977). These alternate intentions are apparent in non-formal writings (e.g., personal diaries, correspondence with associates), but, for various reasons, are not mentioned in formal communications of scientific work. On the contrary, research publications, not only omit the non-scientific background, but are also structured to present a rationalized picture of the scientists' activities, which is (intentionally or not) consistent with the view of science that was much later formulated and operationalized by the science education community as the NOS construct.

Explicitness in NOS/NOT teaching can be formulated as planned activities that engage students in reflective and structured discussions. In our case, embedding such EED improved NOS/NOT understanding and thus enforces existing similar claims (Clough, 2006; Lederman, 2007; McComas, 2002; Sandoval, 2003). Moreover, integrating EED in a TLS relates to improvements in students' awareness and reflection habits. Namely, the reflective EED activities served as scaffolds for students to become more aware of what they were doing and possibly more receptive through their exposal to S&T activities. For the specific learning objective investigated in this study, the integration of transitional EED reflective activities as part of the hands-on activities is found to directly connect to effective scaffolds of the development of students' awareness of S&T in an epistemologically informed manner. More specifically, the gradual introduction of the main goal orientation and characteristic methodology of each of the two domains, in association with explicitly encouraging students connect scientific and technological work to their classroom work associates to improved awareness of the overarching goals of S&T and their facility to use this awareness as a way to distinguish between the two fields.

5.2 Contribution of the study and implications for future research

This study investigated how the combination of inquiry-oriented and design-based learning can provide a rich context for teaching epistemological issues about differences and connections between S&T, thus contributing towards improving efforts to raise students' awareness of these issues. For this purpose, we examined secondary students' awareness of the distinction between S&T prior to and after two implementations of two versions of a TLS on electromagnetic properties of materials. The main difference between the two variants was the presence of EED about distinctions and interconnections between S&T in the second version.

Care was taken to control for other variables that might possibly influence the learning outcomes, such as teaching time and teaching style (see section 3.2.1). As mentioned in section 3.3 (Educational Setting Constraints), the educational background of the participants in the *non-EED* group would potentially lead them to attain higher gains in a S&T course as compared to the less committed and less interested students who participated in the *EED* group. However, additionally to the reasons mentioned in that section, this assumption was also in retrospect not verified through the findings of the study and therefore did not put into question the validity of the research design. The less committed students performed better, showing markedly greater improvements. Had the participants in the two cases been equally competent, it is plausible to predict that the findings of this study would have revealed even greater differences in favor of the explicit approach followed in the EED version of the TLS.

The data collection process relied on evaluating students' awareness of the distinction between the overarching goals of S&T prior to and after the two implementations. Based on the results, according to the definitions adopted in the study about the overarching goals of S&T, the contribution of the study can be identified in two aspects of scientific and technological nature, respectively.

Scientifically, the study provides insights into the theoretical assumptions about teaching and learning NOS/NOT. Firstly, the results corroborate the claim from prior research that students' epistemological awareness does not typically emerge as a spontaneous outcome of their exposal to rich inquiry/design educational experiences (Khishfe & Abd-El-Khalick, 2002; Lederman, 1992; Sandoval, 2003, 2005; Sandoval & Morrison, 2003). Specifically, the results from the *non-EED* implementation do not suggest any positive influence of the TLS enactment on students' awareness of the distinction between S&T.

Secondly, on top of highlighting the inability of a TLS enactment that provides rich inquiry and design experiences to improve students' awareness on the specific epistemological learning objective, the study provides encouraging indications about the extent to which this objective could be attained through purposefully designed learning environments. To recapitulate, the most important of these indications include (a) the increased ability of students at the end of the EED enactment to respond to the FT and ED tests in a similar and simultaneously correct manner, (b) the prevailing shift of post-responses towards the first category in the EED implementation, in sharp contrast to the non-EED implementation, (c) the corresponding reduction in the percentage of the non-epistemologically informed categories of responses. Clearly, these indications suggest that it is possible to impact on students' awareness on NOS/NOT issues from a school age and scaffold them in developing informed views in this direction.

An additional scientific contribution of this study in providing empirical support to the claim concerning the effectiveness of teaching approaches that explicitly address epistemological awareness, is that it extends the limited number of comparative studies that report direct comparisons between the implicit and the explicit approach and provides the first report of such research for upper-secondary students and the unique reported for promoting understanding of the interrelationship between S&T.

Concerning the technological contribution of the study, we deem that our work contributes to the validation of a TLS with respect to its facility to promote awareness about the distinction between S&T as a prerequisite for exploring connections between the two domains. This contribution responds to the widely recognized need for research-based and research-validated teaching innovations that integrate explicit aspects of NOS, a learning objective that still receives limited consideration in conventional teaching practice in S&T education (Lederman, 2007; McComas, 2002; Sandoval & Morrison, 2003). The study partially meets this need by proposing an activity sequence for developing students' awareness of a specific NOS aspect and complements prior work on developing an instrument for assessing students' awareness of the distinction between S&T.

The study has drawn on data restricted to one of the four-targeted NOS/NOT objectives, i.e., the different overarching orientation of S&T. In Study 1, we have documented that understanding differences between S&T is a prerequisite for developing awareness about the strong interactions between S&T and specifically how one field can contribute to the development of the other. It is important to state that the project's research orientation is not to provide science education with a sharp distinction between S&T. The project draws on the premise that trying to think about this distinction can lead to a better understanding of what can clearly be classified as Technology and what can clearly be classified as Science.

Findings presented in this study stress the importance of future research on the design, development and validation of TLSs for helping students in the age range 15 to 18 to develop an awareness of the role of S&T in society and also of their differences and interconnections. More specifically, findings of the study highlight the need for future research on evaluation strategies for other learning objectives related to NOS / NOT. Moreover, building on the successful triangulation strategies of this study, we are interested in exploring the added value possibilities of alternative evaluation strategies diverging from the formal pre-post tests, which could be more context-based and used during teaching in ways that provide students with feedback about their awareness and thus scaffold the integration of epistemological reflections in science classes. We consider the comparisons of data from various evaluation formats a promising possibility for improved resources for assessing learning.

CHAPTER V

The educational value of coherence in designing science teaching-learning sequences that integrate philosophical issues: an example from developing awareness of the relationship between science and technology

Abstract

This study examines the role of philosophy in the educational decision-making involved when designing teaching-learning sequences (TLSs) for science. To illustrate our argument, we focus on a single learning objective: developing awareness of the relationship between science and technology. We present and compare four philosophical perspectives that describe the relationship between science and technology as two domains of social activity, namely: the "indistinguishable fields" view, the demarcationist view, the "technology as applied science" view and the materialistic view. Next, we reflect on implications of applying each individual perspective for the design of TLSs in science and technology education. From this analysis, we conclude that exclusive adoption of any one of these four approaches would lead to flaws in the design of TLSs with significant implications on emergent student views. Inspired by the inference to the best explanation methodology (Harman, 1965; Lipton, 2003) we propose an approach that emphasizes coherence as a guiding principle in designing philosophically informed TLSs on the relationship between science and technology. From this illustrative example, we scaffold a broader coherence argument to support the claim that the design of TLSs for introducing philosophical aspects of science should transgress individual philosophical perspectives and help students develop the more fundamental ideas while overlooking the intricacies of the underlying philosophical dialogue. We identify the interactionist view of the relationship between S&T as one such approach that meets the coherence criteria and we discuss implications of adopting this view in the design of philosophically informed TLSs.

Keywords

teaching-learning sequence; relationship between science and technology; nature of science; nature of technology

1. Perspectives on the relationship between S&T

The phrase "science and technology" is commonly used in policy documents, the daily press and in informal discourse, referring to a single concept or at least two indistinguishable aspects of one enterprise. This public representation contrasts with the philosophical act of probing into the relationship between Science and Technology (S&T). This philosophical discourse is summarized in Figure 1. The four axes ends represent four inferences of the relationship between S&T; at the cross-section of the two axes is a fifth inference. The diagram represents four different perspectives on the relationship between S&T that are present in the ongoing philosophical discourse.

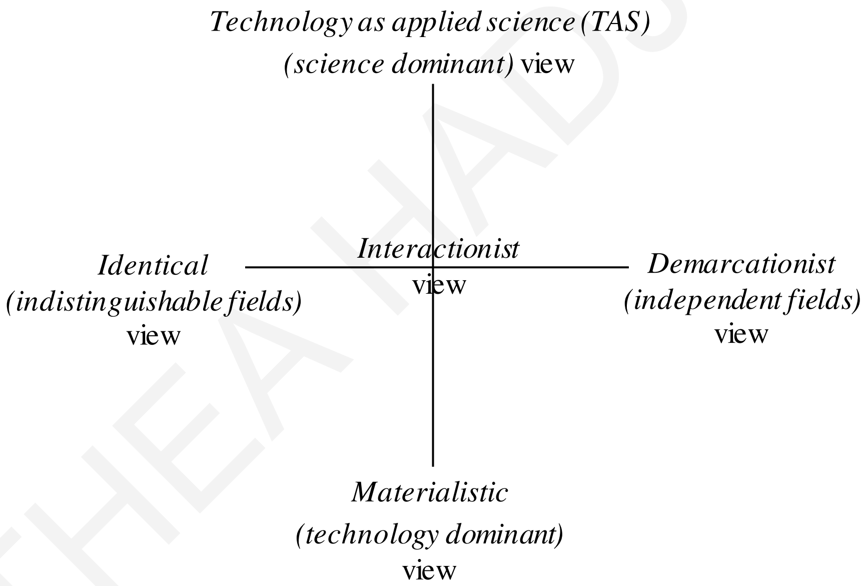

Figure 5. Perspectives on the relationship between Science and Technology (S&T)

The *identical (indistinguishable fields) view* reflects the broad public perception that S&T are two facets of the same coin. This view sees no value in discriminating between S&T and is reinforced by the fact that modern science rarely develops without technology and vise-versa. "Hence modern technology can be seen as deliberately scientific in nature, and contemporary science is largely geared to technological ends, using technological means to achieve them." (Davies, 1995, p.102). Additionally, reports on techno-science education corroborate this view (Tala, 2009). At the other end of the horizontal axis, the *demarcationist view* describes S&T as "independent, with differing goals, methods and outcomes" (Gardner 1994, p.5), and developing separately.

In the vertical axis, the *technology as applied science (science dominant) view* conveys that "science precedes technology, i.e. technological capability grows out of scientific knowledge; this position […] is widely held and influential." (Gardner 1994, p.5). The opposite, *technology dominant view*, rests on the premise that "technology precedes science; this materialist view asserts that technology is historically and ontologically prior to science, that experience with tools, instruments and other artefacts is necessary for conceptual development." (Gardner 1994, p. 5).

At the junction of the two axes, the *interactionist view* treats S&T as domains of human activity with dynamic, two-way interaction (Brooks, 1994) and "considers scientists and technologists as groups of people who learn from each other in mutually beneficial ways." (Gardner 1994, p. 5). Comparatively to the other four, this view seeks to portray a more balanced and rather consensual representation of the relationship between S&T (Davies, 1995).

2. Background

The integration of philosophical issues in science teaching has been a longstanding priority. How to achieve this has been the subject of extensive discussion by the science education research community leading to efforts to promote teachers' and students' understanding of the *nature of science*.

2.1 Nature of Science and Nature of Technology as constructs of the educational sciences

The Nature of Science (NOS) and the Nature of Technology (NOT) have long been considered core learning objectives and fundamental components of scientific and technological literacy (AAAS, 1989; Driver, Leach, Millar & Scot, 1996; ITEA, 2007; Kang, Scharmann & Noh., 2005; Lederman & Lederman, 2014; McComas & Olson, 2002; NRC, 1996, 2000, 2007, 2012; Taber, 2008 among many others). The relationship between S&T, is recognized as one aspect of the NOS/NOT that should be advanced through S&T education and has not been adequately studied thus far (Constantinou et al., 2010; Hadjilouca et al., 2011; McComas, 2008; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

2.2 Assumptions on the design of philosophically informed TLSs

A challenging issue with direct implications on the design of philosophically informed teaching innovations (i.e. integrating NOS/NOT issues in classroom activities), concerns the role of explicitness as a pedagogical strategy. Explicit approaches deem that students' attention to philosophical issues needs to be overtly targeted through purposefully planned group discourse activities (Oliveira, Akerson, Colak, Pongsanon, & Genel, 2012; Schwartz, Lederman, & Crawford, 2004).

Prior research on investigating explicitness in NOS/NOT teaching examined the role of systematically engaging students in reflective and structured discussions. Relevant literature suggests that embedding such Explicit Epistemological Discourse (EED) activities and engaging students in EED facilitates NOS understanding, i.e., there is value in approaching NOS as a learning objective and consequently in planning teaching in ways that explicitly draw students' attention towards NOS issues (Clough, 2006; Khishfe & Ab-El-Khalick, 2002; Lederman, 2007; McComas, 2002; Sandoval & Morrison, 2003).

In our work, we choose to focus on two pedagogical perspectives for the design of TLSs. Inquiry-based and design-based teaching and learning are established paradigms in S&T education. The inquiry-based teaching and learning framework seeks to enhance the authenticity of school science, while at the same time placing emphasis on conceptual change and the emergence of coherent conceptual frameworks through active participation of students in processes of investigating phenomena and constructing meaning (NRC, 2012; Kyza et al., 2011). Design-based teaching and learning also facilitates active learning, this time through engaging students in problem solving processes with explicit reference to meeting life's challenges and social priorities (ITEA, 2007). It involves the methodical design and often the construction of artifacts followed by an evaluation of the extent to which the end product or process meets pre-defined specifications (Bybee, 2011; ITEA, 2007).

3. Designing teaching-learning sequences from different philosophical perspectives: main features and consequences

Davies (1996) provides arguments both in favor and against each one of the four perspectives illustrated in Figure 1 and reports corresponding pedagogical implications to advance the thesis that "the view we take of the relationship between science and technology will, necessarily affect the way we teach them" (p.102). Depending on which view is adopted, there are implications both for the design of a teaching-learning sequence (TLS) and its enactment. Below we describe the main generalized features of TLSs designed from the perspective of each of the four views and we also formulate the student views that would emerge as anticipated outcomes.

3.1 Identical (indistinguishable fields) view

This view would be reasonably expressed by means of an integrated subject "science and technology" or teaching and learning activities that seamlessly transverse the worlds of theoretical ideas, natural phenomena, artifacts and problems that can be addressed through innovative design. A typical TLS would include a blend of scientifically-natured (inquiry-oriented) and technologically-natured (design-oriented) activities without providing any hints that would make students aware of any boundaries between these worlds. During these activities, students would try to respond to questions about explaining phenomena and also solve problems by specifying, developing and evaluating artifacts.

Applying this view through such an undifferentiated approach, disregards that S&T assume inherently different ways of thinking, different methodologies and different priorities. As a consequence, it is possible that any superficial attempt at blending S&T activities could mislead, confuse or enhance existing misconceptions about "what is" and "what is not" science or technology. One possible response to the critique of the indistinguishable fields' view could be given by adopting the demarcationist perspective for the design of TLSs.

3.2 Demarcationist (independent fields) view

Following the demarcationist perspective, separate and mutually exclusive TLSs for each field would reasonably be prepared for possibly separate subject areas, with distinct content and terminology. Activities would be clearly categorized as scientific or technological with mere use of technology in science lessons and vise-versa, e.g. use of tools of modern technology's achievements during science lessons, without exposing students to design processes or aspects of the nature of technology. Correspondingly, technology lessons, would apply scientific knowledge whenever required, without necessarily challenging students to explain relevant phenomena or develop a consistent understanding of related scientific concepts. Several educational systems have indeed adopted this perspective when introducing Technology or Design and Technology as a separate subject (De Vries, 2009; Jones & Buntting, 2015), often replacing Handicraft or Art and Craft, while leaving Science as a largely untouched amalgamation of Physics, Chemistry and Biology units.

A consequence of this approach that often arises is that students' ability to transfer knowledge from science lessons to technology activities and vice-versa is impeded (Jones & Buntting, 2015). Another relevant consequence relates to the fact that applying this approach for the design of TLSs does not accurately represent nor do justice to the actual research reality where the two fields mostly if not always, coexist and interact. Accordingly, students would not be likely to appreciate the contribution of one field to the other, since no bridging between the two lessons would be achieved. This condition could produce false impressions of how the two fields operate as well as their individual value. Subsequently, it could lead to misguiding students' perceptions concerning future career aspirations.

3.3 TAS (science dominant) view

This view would affect the academic role of science education on technology education. TLSs expressing the TAS view would be designed to place emphasis on the academic prestige of science in comparison with technology and the industrial application of scientific knowledge. Most technological projects would be carried out in terms of applying scientific knowledge, with emphasis on the practical side of construction work. If there would be two separate school subjects, the Technology subject would be designed to fit and apply the content learnt in the Science subject. In other words, explaining the relevant phenomena in the Science subject would always be a prerequisite for developing the concepts needed to invent adequate solutions within the projects undertaken in the Technology subject, such as in the case of scientific investigations about electric circuits followed by constructing a torch, for example (Davies, 1995).

A consequence of this approach is that the value of developing design skills could, by and large, be degraded as compared to gaining scientific knowledge (Gardner, 1994). Although historically valid in several instances, in the industrial and post-industrial economy, the TAS view of the relationship between S&T ignores both the fact that, in historical terms, technology preceded science, as well as the current, reciprocal relationship, since: (a) scientific knowledge frequently needs elaboration before it becomes technologically useful (Layton, 1993), (b) many examples of technological development occurred without scientific scaffolding (Basalla, 1988; Jones, 2012), (c) numerous examples of careful application of scientific knowledge failed because of critical design flaws or the absence of other necessary parameters (Davies, 1995; Jones, 2012), and (d) science itself was inspired by technological practices and in many cases was dependent on them (as in the cases of telescopes, computers and particle accelerators, for example) (Pitt, 2018). All these could misguide students to underestimate the significance of technological knowledge and innovation vis-à-vis scientific knowledge and inquiry. This would in turn undermine efforts to develop realistic notions in the students' aspirations and future career choices (Davies, 1995).

3.4 Materialistic (technology dominant) view

In the case of adopting a materialistic approach when designing TLSs, science education would serve much like an assistant to technology education. Specifically, science education would be invoked only on a need to basis, i.e., to investigate certain scientific concepts whose necessity would arise during the implementation of a technology project (e.g., investigation of the thermal insulation properties of various materials as a resource activity for a project with a mission to design a ski jacket) (Davies, 1995).

Although this view, just as the opposite one of TAS, has been historically valid in a variety of situations and historical periods, one of its consequences could be that it leads to disregarding the importance of its converse, i.e. the equally valid inspirational role of scientific development towards technological innovation. Restricting scientific learning activities to an absolutely utilitarian part of the design process, would qualify technology education to the status of being unrealistic: without the contribution of science it is highly unlikely that modern technology could have developed. Additionally, important aspects of science would possibly be left outside the curriculum, since most things taught would be confined to meeting the needs of specific technological projects (Davies, 1995). Lastly, it would be less likely for students to develop the notion of the evolution of scientific knowledge as a process sometimes driven by an innate need to be able to understand and make valid predictions.

4. A coherence view for familiarizing students with the relationship between S&T

The effort to integrate philosophical issues in science and technology teaching beyond being a longstanding priority, is also particularly challenging when it comes to issues that are still open to philosophical scrutiny, such as the relationship between S&T. The design of TLSs, as tools for classroom use, faces exactly this challenge. As illustrated by the analysis in the last section, drawing exclusively on anyone of the four philosophical perspectives on scrutinizing the relationship between S&T, educationally, is not an option. It is not an option partly because the main aim of the educational effort is to encourage student awareness of the distinct roles and priorities of S&T in a modern democratic society, as well as to help students recognize their main features, their dynamic interconnections and their significance.

Having rejected the possibility of adopting anyone of the four philosophical perspectives, two options remain: either to present all four and try to engage students in appreciating the underlying philosophical discourse or to identify a single narrative that crystallizes some fundamental ideas for philosophical reflection.

For the first option, one needs to take into consideration that the objective of the corresponding philosophical scrutiny is to seek an exhaustive account that can guide informed debate about the very nature of science and the very nature of technology, in ways that satisfy the criterion of validity and consistency but also have the potential to influence informed policy development and decision making in terms of setting scientific and technological priorities. Such an account would require a pre-existing understanding of the concept related to the specific topic as well as the fundamental functions of S&T and also a basic facility with philosophical inquiry. In addition, students would need to be able to connect with an account for S&T that they can relate to their own studies and options for the future.

In contrast, for the second option, if we were to adopt some of the shared ideas, we need to beware of two challenges: (a) the need to identify philosophical ideas that are to some degree consensual, revealing fundamental aspects of the purposes and relationship between science and technology; (b) the need for those ideas to make a coherent whole so that they can be conducive to elaboration.

For these purposes and following on our critique of exclusively adopting any one of the four approaches when designing TLSs, we propose adopting a methodology inspired by what Harman (1965), and Lipton (2003) –albeit in a different context– call *inference to the best explanation*, i.e. in the absence of significant empirical evidence that would be crucial for determining the one correct approach, to aim for the best possible method for introducing the relationship between S&T in each development stage.

The inference to the best explanation leads one to infer that it must have rained the night before because the grass is wet this morning, since it is a highly probable conclusion if the experience occurs in a northern European country. It would not have been an inference to the best explanation if the experience occurred in a southern European country in the summer, since the probability of the conclusion diminishes significantly, even more so if the road next to the grass is dry. So, the same inference would be good or bad given the accompanying circumstances in the neighboring environment. Let us codify this by saying that an inference leads to the best explanation given the context of the circumstances in which it occurs. In an analogous manner we suggest that, since we lack conclusive arguments for deciding which of the four aforementioned approaches is best for use in the design of TLSs, we adopt a pluralist approach in the sense of choosing the best one, or the most suitable, given the circumstances at particular stages of the development of the students' knowledge and understanding.

For the case of familiarizing students with the relationship between S&T, the best possible approach needs to satisfy the following: Firstly, it should transgress problems arising when exclusively following any specific view of the relationship between S&T.

Secondly, it should reconcile between the various philosophical interpretations. Despite the lack of agreement in the philosophy of science in a specific interpretation of the relationship between S&T, it would still be possible, meaningful and useful to help students develop a relevant set of fundamental ideas while overlooking the intricacies of the underlying discourse. Subsequently, citing the absence of actual application of the individual views of the relationship between S&T in education, we suggest a response to this open issue by introducing a *coherence approach* (as mentioned, inspired by Harman's (1965) inference to the best explanation approach).

Instead of presenting one or more of the active philosophical perspectives of the relationship between S&T, a *coherence approach* would include consensual elements extracted from all four perspectives in order to familiarize students with an overview of the relationship between S&T through suitable examples, highlighting the fundamental distinctions and interconnections even though this view would not be compatible with all the intricacies of an exhausting philosophical debate. One implication of the coherence approach is that the significance of any of the above four views for introducing TLSs is considered as context-dependent. This prima facie may not seem appropriate, but in the absence of conclusive arguments that one approach is best, for the practical purposes of designing a TLS, it is reasonable.

One such coherent approach would be to adopt an interactionist view of the relationship between S&T. According to Davies (1995) the most appropriate view to understand the other views is the one at the junction of the two dimensions of Figure 1, i.e., the interactionist view. Thus, applying the interactionist notion through the design of TLSs in S&T education balances the two ends of TAS and materialistic views, reflecting the current reality of how S&T research projects are enacted in the real world. Admittedly, "it is very difficult to teach science and technology interactively", especially in the primary school (Davies, 1995, p.110). Furthermore, if students have not previously been given the opportunity to develop a consistent understanding about the differences between S&T, helping them recognize aspects of the intricate relationship between the two fields would involve some degree of elaboration on the bidirectional transactions that, for example, feed science with questions formulated by technology and tools developed by technology and, in the other directions, feed technology with phenomena, laws and scientific hypotheses that can find use in technological problem solving.

To achieve implementation of such a coherence approach, one could be guided by awareness of key ideas from the historical background of the relationship between S&T, and carefully adapt them seeking to align the complexity of the targeted ideas with students' cognitive resources. Following the historical development of the relationship between S&T, we learn that initially the two fields developed independently and today they have come to progress in mutual interaction (Hadjilouca et al., 2011). Thus, students could initially be guided to study separately the two fields (demarcationist view) and be steered to develop coherent criteria to distinguish between S&T. One basic and historically relevant criterion is the different orientation between S&T, where science seeks to generate reliable knowledge, while technology seeks to respond to human needs by developing solutions to problems (Hadjilouca et al., 2011). Corresponding differences exist in terms of the core processes they rely on, i.e. investigation is a process employed for achieving scientific goals, while design is a procedure applied for reaching technological goals (Hadjilouca et al., 2011). Ensuring that students are familiarized with fundamental distinctions between S&T, then a TLS can proceed with activities that explore the coexistence of the two fields, to explore their interconnections as these appear through the TAS and the materialistic views.

Based on such a coherence rationale, we have designed a TLS, which we described analytically in another study (Hadjilouca et al., 2011). This teaching proposal, as elaborated in Chapter III, was implemented with an intact class of sixth graders and we have obtained promising results regarding reaching its learning objectives for distinguishing between S&T and also appreciating their relationship.

In summary, the coherence approach employs elements from all four views in the quest to introduce an interactionist relationship between S&T. However, it does not do so in order to spell out necessary and sufficient conditions for the difference between S&T, but in order to support the development of intuition about their different nature and their relations. In this quest, the coherence approach employs each of the four views at different stages of the development of that intuition in students or it chooses the most suitable of the four in each particular circumstance, since its compass is to bring students to a basic level of understanding of S&T that will allow them to recognize some of the differences and interdependencies between S&T.

5. A broader coherence claim concerning the design of science TLSs

One could argue why not teach all views of the relationship between S&T instead of probing on a coherence approach. The answer is simple; neither science nor technology education are oriented to teaching philosophy. Still, both science education and technology education, from the designers' perspective, are interested to probe how philosophy can inform decision-making concerning the design of TLSs that integrate philosophical aspects of S&T into teaching and learning.

Although philosophical views cannot determine educational practices, we think that it is meaningful for educators to maintain a sufficient philosophical background with the intention of following future discourse in which philosophy could possibly play a greater role in education. Despite the lack of agreement in the philosophy of science/technology on a specific interpretation of the relationship between S&T, it would still be possible and useful to help students develop a relevant set of fundamental ideas while overlooking the intricacies of the underlying discourse. In the previous section we proposed an approach for familiarizing students with the relationship between S&T, which transgresses complicated philosophical scrutiny, namely the coherence approach. In this section we extend this approach by suggesting its broader use in the design of TLSs that scaffold students' awareness of more issues relevant to philosophical aspects of science that are also considered important in science education and simultaneously remain open to philosophical debate. We argue in favor of extending the coherence approach by reporting the consistency of this extension with the recent efforts of science education researchers to define the construct of the NOS, as a synopsis of general characteristics of science that are meaningful and beneficial for students to be aware of and for which there is a consensus among philosophers of science (Abd-El-Khalick, Bell & Lederman, 1998; Lederman, 2007; McComas, 2008; Osborne et al., 2003). In fact, understanding how S&T differ and relate is part of this construct (Jones & Buntting, 2015; McComas, 2008; Osborne et al., 2003).

More specifically, the coherent approach is consistent with the consensus that seems to exist within science education on a set of ideas consisting of the NOS (Abd-El-Khalick, Bell & Lederman, 1998; Lederman, 2007; McComas, 2008; Osborne et al., 2003). For example, these ideas include, amongst others, the durable, albeit tentative, nature of scientific theories, the central role of empirical evidence in science and the distinction between observations and inferences. This consensus rationale results from the premise that whatever the scientific content students are intended to gain (e.g. conceptual understanding, NOS understanding, reasoning skills, practical skills, experiences, attitudes), it should be appropriately transformed toward meeting students' needs and use their ideas as a starting point. Consequently, transformations are bound to include justified simplifications of the scientific content that align the complexity of the targeted ideas with students' cognitive readiness.

The challenge that is inherent in attempts to devise teaching transformations for philosophical issues, is how to avoid conflicts with corresponding ideas that are widely accepted within the philosophy of science. Despite being simplified and incomplete, the ideas that students are intended to develop should serve a productive role and should be amenable to elaboration at subsequent stages so as to become increasingly sophisticated and epistemologically coherent (Taber, 2008). From this perspective, disagreements among philosophers of science are not always relevant to school science (Lederman, 2007), in that science teaching merely aims at helping students develop fundamental consensus ideas of how science works without trying to deepen in the underlying (philosophical) discourse.

It is important to note, that the relationship between S&T, is included among the set of ideas consisting of the NOS (McComas, 2008; Osborne et al., 2003). Of course, familiarizing students with the relationship between S&T is itself important for a number of reasons, which have been elaborated elsewhere (Constantinou et al., 2010). Understanding of the relationship between S&T could inform and facilitate attempts to devise mechanisms for increasing students' interest towards S&T courses (Gago et al., 2004; NSF, 2003; OECD, 2006) and it could offer them guidance on future careers. Specifically, it could help the education system to encourage students to make more informed decisions and this could, in turn, increase the likelihood for successful career choices. Also, the prevalent conceptions about S&T are important for efforts to communicate publicly their role in society and the outcomes of the various policy procedures for developing funding priorities. For instance, the level of public support for an innovation system in close symbiosis but distinct from the science system, and closely related with financial investment mechanisms, is directly related to the level of public understanding of the differences and connections between S&T and the diverse roles they play in economic development.

Our objective in this study was to reflect on the educational value of coherence when designing TLSs for teaching issues related to the philosophy of science and suggest its application in a specific example. Notably, we used the objective of familiarizing students with the relationship between S&T as an example to support the claim that designing TLSs for teaching issues related to the philosophy of science, should be structured on philosophically informed decisions but not restricted to individual philosophical interpretations.

CHAPTER VI: CONCLUSIONS

1. Restating the research problem and purpose

Developing understanding about the NOS, is acknowledged as a core learning objective of science education and an important component of scientific literacy (AAAS, 1989; Abd-El-Khalick, 2013; Driver et al., 1996; Kang et al., 2005; Lederman, 2007; McComas & Olson, 1998; NRC, 1996, 2000, 2007, 2012; Taber, 2008 among many others). However, conventional science teaching does not pay adequate attention to NOS as it does with the remaining science learning objectives (e.g. conceptual understanding, scientific skills, etc.) as compared to this acknowledgement. The present dissertation emerged as a partial response to this problem and specifically the dual need for (a) elucidating parameters that relate to the teaching and learning of the NOS in science education and (b) developing corresponding illustrations of effective teaching innovations, especially in the lower school grades (Abd-El-Khalick, 2012, 2013; Akerson & Volrich 2006; Kang et al., 2005; Lederman, 2007; Lederman & Lederman, 2014; Sandoval & Morrison, 2003). One of these parameters concerned the role of the philosophy of science in the design of TLSs , while another concerned the role of EED for improving students' awareness about NOS.

I was especially interested to pursue the above purpose by focusing on an aspect of the NOS which lacked adequate investigation thus far. Specifically, the dissertation elaborated on the role of Science and Technology in society, their interrelationship and sought to investigate student understanding of this role and ways to enhance it. The interrelationship between S&T is of contemporary interest because of the need to make better use of the results of research in innovation and entrepreneurship. Science education has a great potential in contributing to this societal priority by promoting student understanding of how S&T differ and how they relate (Jones & Buntting, 2015; McComas, 2008; Osborne et al., 2003).

2. Summary of findings – Limitations

The dissertation pursued its purpose through four distinct studies that sought to respond to the formulated research questions. The *first study* developed a detailed description of the rationale underlying a novel teaching proposal and an outline of the corresponding activity sequence that embodied the rationale for a teaching innovation about the interrelationship between S&T. The effort relied on inputs from three sources: the history and philosophy of

S&T, existing knowledge on the teaching and learning of the NOS, as well as empirical data on students' initial ideas and the difficulties they encounter while learning about this topic.

The *second and third studies* designed TLSs that applied this rationale and evaluated them through teaching interventions. Both studies evaluated the effectiveness of EED for raising students' awareness about NOS by exploring whether the combination of inquiry-oriented and design-oriented teaching and learning could provide a rich context for raising awareness about the interrelationship between S&T. The learning objectives of the TLSs in both studies were that students would (a) develop awareness of the distinction between the different overarching goals of S&T (producing reliable knowledge about natural phenomena vs developing solutions to respond to human problems and needs), (b) develop awareness of the difference in the core methodological frameworks that are commonly adopted by S&T (investigation and design, respectively), (c) identify aspects of the contribution of S to the development of T, and (d) identify aspects of the contribution of T to the development of S. Assessment focused on the first learning goal, namely student awareness of the distinction between the different overarching goals of S&T. Both studies described the research process and what was learnt about designing TLSs on this topic, accompanied by suggestions on improvements and refinements to the learning materials.

Specifically, the *second study* reported a process of technological design situated in a design-based research paradigm that implemented a specially designed TLS in geometrical optics with a class of upper-elementary school students. The effectiveness of the TLS was assessed with measurements of students' understanding about the different overarching goals of S&T and also difficulties students encounter in their attempts to develop an understanding of the difference between the overarching goals of S&T. The measurements were taken prior to and after the teaching intervention through the participants' responses to written tasks and follow-up semi-structured interviews. The analysis of the collected data explored students' progress because of their interaction with the TLS. The results demonstrated the possibilities in young learners' ability to improve their understanding and provided feedback for the revision of the TLS so as to further enhance its effectiveness by further scaffolding students overcome their difficulties and better achieve the stated learning objectives in future implementations.

The *third study* integrated, as previously stated, the epistemologically oriented learning objectives and corresponding activities regarding the interrelationship between S&T in an existing TLS on electromagnetic properties of materials and was designed to address the needs of upper-secondary school students. Next, it applied a combined pre-post test and interview design that evaluated upper-secondary school students' awareness of the interrelationship between S&T as part of two teaching interventions with two versions of a TLS. The targeted difference between the two interventions was the integration of EED activities regarding the interrelationship (i.e., differences and connections) between S&T in the second version of the TLS. The outcomes of the study provided empirical evidence regarding the argument that students' awareness of NOS was more effectively promoted when integrating EED in science teaching and learning.

The results of the TLSs' evaluations in the second and third studies concentrated to one of the LOs that is a prerequisite for exploring connections between S&T. The promising results at this stage, necessitate to consider for further enhancing the development of validated instruments for the rest of the objectives, in order to collect feedback about the remaining learning objectives.

The *fourth study* focused on the role of philosophy in the design of TLSs that introduce philosophical aspects of science, such as the relationship between S&T. The study compared five reported perspectives that describe the relationship between S&T and reflected on corresponding implications from separate application of each perspective for the design of TLSs in S&T education. This reflection concluded that exclusive adoptions of any of these five approaches when designing TLSs reported flaws and lacked validity in students' awareness. This reflection led to suggesting a coherence approach when designing TLSs for familiarizing students with the relationship between S&T. This approach suggests such a TLS needs to be structured on philosophically informed decisions but not to be restricted to individual philosophical interpretations. The example of the relationship between S&T was further expanded in supporting a broader coherence claim concerning the design of TLSs for introducing philosophical aspects of science by transgressing the individual philosophical perspectives and help students develop fundamental ideas while excluding the intricacies of the underlying philosophical dialogue.

3. Implications – Contribution

Possessing an adequate understanding concerning how S&T differ and interrelate has implications on various dimensions including citizens' ability to meaningfully participate in the public debate over socio-scientific issues and make informed choices on their future careers. The contribution of this dissertation is of a dual nature: scientific and technological.

One scientific contribution of the dissertation relates to indications of the ability to impact on students' understanding on NOS issues at an early stage and scaffold students in developing informed views towards this direction. Particularly, the dissertation's findings elucidate our understanding about the role of explicitness in teaching about NOS issues. EED in Studies 2 and 3 was applied as planned activities that engaged students in reflective and structured discussions. Embedding such EED improved NOS understanding. The findings of both studies (2 and 3) that EED was integrated in the TLSs, exposed improvements in students' awareness and reflection habits. Namely, the reflective EED activities served as scaffolds for students to become more aware of what they were doing and possibly more receptive through their exposal to S&T activities. For the learning objective investigated in these studies (to understand the difference between the overarching goals of S&T), the integration of transitional EED reflective activities as part of the hands-on activities was found to directly connect to effective scaffolds of the development of students' awareness of how S&T differ in an epistemologically informed manner. More specifically, the gradual introduction of the main goal orientation and characteristic methodology of each of the two domains, in association with explicitly encouraging students connect scientific and technological work to their classroom work associates to improved awareness of the overarching goals of S&T and their facility to use this awareness as a way to distinguish between the two fields. Therefore, such findings confirmed and elucidated the claim that students' NOS awareness does not typically emerge as a spontaneous outcome of their exposal to rich inquiry/design educational experiences (Khishfe & Abd-El-Khalick, 2002; Lederman, 1992; Sandoval, 2003, 2005; Sandoval & Morrison, 2003) but can improve when systematically engaging students in structured reflective discussions during teaching and learning (Clough, 2006; Lederman, 2007; McComas, 2002; Sandoval, 2003). The dissertation's novelty in this respect becomes more apparent since only a limited number of research reports with direct comparisons between the implicit and the explicit approach (study 3) and no prior results were found for the interrelationship between S&T (studies 2, 3).

Another scientific contribution relates to investigating the potential of using inputs from the history and philosophy of S&T for facilitating and supporting attempts to develop teaching and learning materials that address NOS issues. Specifically, exposing the perspectives of the interrelationship between S&T through the lens of history revealed guidelines that informed the development of the activity sequence in various ways. The findings from such reflection can also be useful for any future attempt to design NOS-informed learning sequences. Connected to this contribution stands the suggestion of the coherence approach when designing TLS that introduce philosophical aspects of science, i.e., NOS aspects. Using the relationship between S&T as an example, the coherence approach employed elements from the various philosophical interpretations of the relationship between S&T in the quest to introduce TLSs on this topic. This approach could not be used for spelling out necessary and sufficient conditions for the difference between S&T, but it can be useful in educators to support students' development of intuition about the two fields' different nature and their relations. In this quest, the coherence approach was useful to employing each of the five views at different stages of the development of that intuition in students or it chose the most suitable of the five in each particular circumstance, since its compass was to bring students to a basic level of understanding of S&T that would allow them to recognize some of the differences and relations between S&T.

The technological part of the dissertation's contribution relates to the development of a structure for a teaching innovation addressing the interrelationship between S&T with upper-elementary and secondary school students. The dissertation contributed to the design as well as the validation of TLSs with respect to their ability to promote awareness about the distinction between S&T as a prerequisite for exploring connections between the two domains. This contribution responded to a widely recognized need for research-based and research-informed teaching innovations that integrate explicit aspects of the NOS, a set of learning objectives that still receive limited consideration in conventional teaching practice (Abd-El-Khalick, 2012; Lederman, 2007; Lederman & Lederman, 2014; McComas, 2002; Sandoval & Morrison, 2003), especially in the case of the elementary and secondary school grades (Akerson & Volrich, 2006; Kang et al., 2005).

Finally, another contribution relates to a topical issue in the Cyprus Educational System for public elementary education. The dissertation is directly connected to recent changes of the framework for teaching S&T, where for grades 1-4 two lessons, *Science* and *Design and Technology*, have recently been integrated after a long tradition of being taught separately with quite distinct laboratory infrastructures and traditions. This transformation is a cause for further thinking on the pedagogical grounds on which to base decisions about the ways of effectively integrating the two fields in early elementary education. The findings of the dissertation contribute in this direction, through specific recommendations for effective teaching of S&T in ways that take into consideration the interrelationship between the two domains.

4. Recommendations for future research

Future steps on this research area include more implementation circles of the revised TLSs in upper elementary and secondary classroom environments with a view to evaluate their effectiveness through appropriate instrumentation and to further promote all the learning objectives. The two empirical studies (2 and 3) have drawn on data restricted to one of the four-targeted NOS objectives, i.e., the different overarching orientation of S&T. The two theoretical studies (1 and 4), documented that understanding differences between S&T is a prerequisite for developing awareness about the strong interactions between S&T and specifically how one field can contribute to the development of the other. It is important to state that the project's research orientation is not to provide science education with a sharp distinction between S&T. The project draws on the premise that trying to think about this distinction can lead to a better understanding of what can clearly be classified as Technology and what can clearly be classified as Science.

The empirical findings presented in this dissertation stress the importance of future research on the design, development and validation of TLSs for helping students in the age range 11 to 17 to develop an awareness of the role of S&T in society and also of their differences and interconnections. More specifically, these findings highlight the need for future research on evaluation strategies for other learning objectives related to NOS. Moreover, building on the successful triangulation strategies, I am interested in exploring the added value possibilities of alternative evaluation strategies diverging from the formal pre-post tests, which could be more context-based and used during teaching in ways that provide students with feedback about their awareness and thus scaffold the integration of epistemological reflections in science classes. I consider the comparisons of data from various evaluation formats a promising possibility for improved resources for assessing learning.

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APPENDICES

Appendix A: List of abbreviations

Appendix B: Evaluation task used in Study 2 of students' ability to distinguish between S&T based on the different central objective each field pursues (in English and in Greek Language)

Appendix C: Evaluation task used in Study 3 of students' ability to distinguish between S&T based on the different central objective each field pursues (in English and in Greek Language)

Appendix D: Semi-structured interview protocol used in Studies 2 and 3

Appendix E: Teaching-Learning materials used in Study 2

Appendix F: Teaching-Learning materials used in Study 3

Appendix A: List of Abbreviations

Table 6

List of Abbreviations

Abbreviation	Explanation
EED	Explicit Epistemological Discourse
LO	Learning Objective
NOS	Nature of Science
NOT	Nature of Technology
S&T	Science and Technology
TLS	Teaching-Learning Sequence

Appendix B

Formal Terminology test

Name: ____ Class: _______ Date: __________

Below there are some statements that describe what different researchers are trying to do in their research. For each research tick ✓ **ONE** box, which you consider as the most appropriate, i.e., whether you consider that the research fits in **science**, **technology** or **neither** of the two fields**.**

		What the researchers are trying to do belongs to science.	**What the researchers are trying to do belongs to technology.**	**What the researchers are trying to does not belong neither science nor technology.**
1.	We try to design faster aeroplanes.			
2.	We try to explain how lightning is created.			
3.	We observe the sky through telescopes in order to study the motion of planets.			
4.	We are searching to find the best way to measure with accuracy the speed of the wind.			
5.	We are studying a newly located species in a park, in order to see how it differs from the other known species living in the same park.			
6.	We try to make filters to absorb polluting fumes that are emitted from factory chimneys.			
7.	We try to create a vaccine against various dangerous known viruses.			
8.	We try to understand the causes of cyclones.			
9.	We try to improve microscopes so that we can make more detailed observations.			
10.	We try to understand the behaviour of small species that live in Athalassa lake.			
11.	We try to make an artefact that will protect us from lightning.			
12.	We try to examine how the climate conditions would change if glaciers melted.			
13.	The raw materials that are normally used for producing electricity are oil and coal. The amounts of these materials are continuously reducing, so we try to find new ways of producing electricity.			

		What the researchers are trying to do belongs to **science**.	What the researchers are trying to do belongs to **technology**.	What the researchers are trying to does not belong **neither science nor technology**.
14.	We do experiments with car machines in order to find a way to reduce polluting fumes that are emitted from factory chimneys.			
15.	We try to explain what causes tsunami.			
16.	We try to study the factors that cause various types of cancer.			
17.	We take monthly water flow measurements of natural streams.			
18.	We try to examine whether we can modify some food, so as to add substances known for their ability to cure some diseases.			
19.	We try to predict how the climate will change in 500 years. We use computers in order to make some complicate mathematical calculations easily and fast.			
20.	We try to investigate how the sun influences our skin			
21.	We try to develop an instrument that will help us effectively predict the time of occurrence and the length of earthquakes.			
22.	We try to make materials that will be more withstand in earthquakes			
23.	We are trying to decide the best location to build a desalination plant.			
24.	Recently, there has been a car accident and now a research is conducted in order to find the causes that led to it.			
25.	Some times arteries that send oxygen to the heart get narrow and this causes heart attacks. We try to examine how smoking leads to the stenosis of the arteries.			
26.	Antibiotics help us in confronting some diseases; however, too frequent use of antibiotics can be detrimental to our health in the long term. We try to understand better what types of problems may be caused by overuse of antibiotics			
27.	We examine whether microwave ovens are dangerous for our health and also what sort of problems they might cause.			

		What the researchers are trying to do belongs to **science**.	What the researchers are trying to do belongs to **technology**.	What the researchers are trying to does not belong **neither science nor technology**.
28.	Many electrical devices (such as mobile phones) transmit large amount of radiation when they are operating and this could cause health problems. We try to make an instrument that measures how much radiation is transmitted by various devices.			
29.	We are trying to develop a substance that acts against known viruses linked to cancer.			
30.	We keep records of the people entered in our country's hospitals with heart problems			
31.	Many people argue that caffeine is bad for our health. This issue has not been studied much so far. We are trying to investigate, so that we can explain how exactly it affects our health.			
32.	In many cases, drinkable water contains substances that are bad for our health. We try to find a way to remove them.			

Question: Concerning your responses in the above table, how do you decide whether a research project fits with the goal of **science** or **technology** or **neither**?

Answer: ____

____

____

____

____

Elaborated Definitions test

Name: ____ Class: _________ Date: ____________

Below there are some statements that describe what different researchers are trying to do in their research. For each research tick ✓ ONE box which in your opinion fits better.

		They try to understand better how natural world functions.	**They try to develop solutions to problems encountered by society and to meet human needs.**	**Neither of the two previous goals interests them.**
1.	We try to design faster airplanes.			
2.	We try to explain how lightning is created.			
3.	We observe the sky through telescopes to study the motion of planets.			
4.	We are searching to find the best way to measure with accuracy the speed of the wind.			
5.	We are studying a newly located species in a park, in order to see how it differs from the other known species living in the same park.			
6.	We try to make filters to absorb polluting fumes that are emitted from factory chimneys.			
7.	We try to create a vaccine against various dangerous known viruses.			
8.	We try to understand the causes of cyclones.			
9.	We try to improve microscopes so that we can make more detailed observations.			
10.	We try to understand the behavior of small species that live in Athalassa lake.			
11.	We try to make an artefact that will protect us from lightning.			
12.	We try to examine how the climate conditions would change if glaciers melted.			
13.	The raw materials that are normally used for producing electricity are oil and coal. The amounts of these materials are continuously reducing, so we try to find new ways of producing electricity.			
14.	We do experiments with car machines in order to find a way to reduce polluting fumes that are emitted from factory chimneys.			
15.	We try to explain what causes tsunami.			
16.	We try to study the factors that cause various types of cancer.			
17.	We take monthly water flow measurements of natural streams.			

		They try to understand better how natural world functions.	They try to develop solutions to problems encountered by society and to meet human needs.	Neither of the two previous goals interests them.
18.	We try to examine whether we can modify some food, so as to add substances known for their ability to cure some diseases.			
19.	We try to predict how the climate will change in 500 years. We use computers in order to make some complicate mathematical calculations easily and fast.			
20.	We try to investigate how the sun influences our skin.			
21.	We try to develop an instrument that will help us effectively predict the time of occurrence and the length of earthquakes.			
22.	We try to make materials that will be more withstand in earthquakes.			
23.	We are trying to decide the best location to build a desalination plant.			
24.	Recently, there has been a car accident and now a research is conducted in order to find the causes that led to it.			
25.	Sometimes arteries that send oxygen to the heart get narrow and this causes heart attacks. We try to examine how smoking leads to the stenosis of the arteries.			
26.	Antibiotics help us in confronting some diseases; however, too frequent use of antibiotics can be detrimental to our health in the long term. We try to understand better what types of problems may be caused by overuse of antibiotics.			
27.	We examine whether microwave ovens are dangerous for our health and also what sort of problems they might cause.			
28.	Many electrical devices (such as mobile phones) transmit large amount of radiation when they are operating and this could cause health problems. We try to make an instrument that measures how much radiation is transmitted by various devices.			
29.	We are trying to develop a substance that acts against known viruses linked to cancer.			
30.	We keep records of the people entered in our country's hospitals with heart problems.			
31.	Many people argue that caffeine is bad for our health. This issue has not been studied much so far. We are trying to investigate, so that we can explain how exactly it affects our health.			
32.	In many cases, drinkable water contains substances that are bad for our health. We try to find a way to remove them.			

Ονοματεπώνυμο: ____ Τάξη: _____ Ημερ/νία: __________

Πιο κάτω βλέπεις δηλώσεις διαφόρων ερευνητών που εξηγούν τι προσπαθούν να κάνουν στην έρευνά τους. Για τον κάθε ερευνητή σημείωσε ✓ σε ΕΝΑ κουτάκι ανάλογα με το κατά πόσο θεωρείς ότι αυτό που κάνει ταιριάζει με τον στόχο της **επιστήμης**, της **τεχνολογίας** ή με **κανένα** από τους δύο κλάδους**.**

		Ο στόχος των ερευνητών ταιριάζει με το στόχο της επιστήμης.	**Ο στόχος των ερευνητών ταιριάζει με τον στόχο της τεχνολογίας.**	**Ο στόχος των ερευνητών δεν ταιριάζει ούτε με το στόχο της επιστήμης ούτε με το στόχο της τεχνολογίας.**
1.	Προσπαθούμε να σχεδιάσουμε αεροπλάνα γρηγορότερα από αυτά που έχουμε σήμερα.			
2.	Προσπαθούμε να εξηγήσουμε πώς ακριβώς δημιουργείται ο κεραυνός.			
3.	Προσπαθούμε να παρατηρήσουμε με το τηλεσκόπιο τους πλανήτες για να εξακριβώσουμε πώς κινούνται.			
4.	Ψάχνουμε να βρούμε τον καλύτερο τρόπο για να μετρούμε με ακρίβεια την ταχύτητα του ανέμου.			
5.	Εμείς έχουμε εντοπίσει πρόσφατα ένα νέο είδος οργανισμού στο πάρκο της Αγλαντζιάς και το μελετούμε ώστε να δούμε σε τι διαφέρει από τους υπόλοιπους οργανισμούς που ζουν εκεί.			
6.	Προσπαθούμε να φτιάξουμε φίλτρα που θα απορροφούν τα βλαβερά καυσαέρια που εκπέμπονται από τα φουγάρα των εργοστασίων.			
7.	Τώρα που γνωρίζουμε αρκετά πράγματα για τον τρόπο με τον οποίο συμπεριφέρονται κάποιοι ιοί όταν προσβάλουν τον ανθρώπινο οργανισμό, προσπαθούμε να δημιουργήσουμε ένα εμβόλιο που θα τους καταπολεμά.			
8.	Θέλουμε να κατανοήσουμε τι προκαλεί τους ανεμοστρόβιλους.			
9.	Προσπαθούμε να βελτιώσουμε τα μικροσκόπια ώστε να μπορούμε να κάνουμε πιο λεπτομερείς παρατηρήσεις.			
10.	Προσπαθούμε να κατανοήσουμε τη συμπεριφορά μικροσκοπικών οργανισμών που ζουν στη λίμνη της Αθαλάσσας.			
11.	Προσπαθούμε να φτιάξουμε κατασκευές που θα μας προστατεύουν από τους κεραυνούς.			
12.	Προσπαθούμε να εξετάσουμε πώς θα επηρεάζονταν οι καιρικές συνθήκες αν έλιωναν οι παγετώνες.			
13.	Οι πρώτες ύλες για την παραγωγή ηλεκτρισμού είναι το πετρέλαιο και το κάρβουνο. Οι ποσότητες αυτών των ουσιών στον πλανήτη μειώνονται συνεχώς και εμείς προσπαθούμε να βρούμε άλλους τρόπους παραγωγής ηλεκτρισμού.			

		Ο στόχος των ερευνητών ταιριάζει με το στόχο της επιστήμης.	**Ο στόχος των ερευνητών ταιριάζει με τον στόχο της τεχνολογίας.**	**Ο στόχος των ερευνητών δεν ταιριάζει ούτε με το στόχο της επιστήμης ούτε με το στόχο της τεχνολογίας.**
14.	Τα αυτοκίνητα εκπέμπουν πολλά βλαβερά αέρια προς την ατμόσφαιρα. Κάνουμε πειράματα με τη μηχανή του αυτοκίνητου στο εργαστήριό μας, ώστε να βρούμε τρόπο να μειώσουμε αυτά τα αέρια.			
15.	Προσπαθούμε να βρούμε τι είναι αυτό που προκαλεί το τσουνάμι.			
16.	Προσπαθούμε να μελετήσουμε τους παράγοντες που προκαλούν διάφορους τύπους καρκίνου.			
17.	Εμείς παίρνουμε μετρήσεις του νερού που ρέει στα φράγματα κάθε μήνα.			
18.	Προσπαθούμε να τροποποιήσουμε κάποια τρόφιμα, ώστε να βάλουμε σε αυτά ουσίες που βοηθούν στη θεραπεία διαφόρων ασθενειών.			
19.	Προσπαθούμε να προβλέψουμε πώς θα αλλάξει (αν θα αλλάξει) το κλίμα στη γη στα επόμενα πεντακόσια χρόνια. Επειδή υπάρχουν κάποιοι πολύπλοκοι μαθηματικοί υπολογισμοί χρησιμοποιούμε ηλεκτρονικούς υπολογιστές, ώστε να τους κάνουμε εύκολα και γρήγορα.			
20.	Ερευνούμε με ποιο τρόπο επηρεάζει το δέρμα μας η ηλιακή ακτινοβολία.			
21.	Προσπαθούμε να φτιάξουμε ένα όργανο μέτρησης, το οποίο θα μας βοηθά να προβλέπουμε πότε θα συμβεί ένας σεισμός και πόσο ισχυρός θα είναι.			
22.	Προσπαθούμε να φτιάξουμε υλικά οικοδομής τα οποία να είναι πιο ανθεκτικά σε σεισμούς.			
23.	Εμείς προσπαθούμε να αποφασίσουμε ποιος είναι ο καταλληλότερος χώρος για κατασκευή μονάδας αφαλάτωσης θαλασσινού νερού.			
24.	Πρόσφατα έχει γίνει ένα αυτοκινητιστικό δυστύχημα και τώρα γίνεται έρευνα για να βρεθούν οι λόγοι που οδήγησαν σε αυτό.			
25.	Μερικές φορές στενεύουν οι αρτηρίες που τροφοδοτούν την καρδιά με οξυγόνο και αυτό προκαλεί τα καρδιακά εμφράγματα. Προσπαθούμε να εξετάσουμε πώς το κάπνισμα οδηγεί στη στένωση των αρτηριών.			
26.	Τα αντιβιοτικά φάρμακα βοηθούν στην αντιμετώπιση κάποιων ασθενειών. Όμως η πολύ συχνή χρήση αυτών των φαρμάκων φαίνεται ότι δημιουργεί νέα προβλήματα στον οργανισμό μας. Προσπαθούμε να κατανοήσουμε καλύτερα τι είδους προβλήματα προκαλεί.			

		Ο στόχος των ερευνητών ταιριάζει με το <u>στόχο της επιστήμης.</u>	Ο στόχος των ερευνητών ταιριάζει με τον <u>στόχο της τεχνολογίας.</u>	Ο στόχος των ερευνητών δεν ταιριάζει <u>ούτε με το στόχο της επιστήμης ούτε με το στόχο της τεχνολογίας.</u>
27.	Εξετάζουμε κατά πόσο οι φούρνοι μικροκυμάτων είναι επικίνδυνοι για την υγεία μας και επίσης τι είδους προβλήματα μπορεί να δημιουργούν.			
28.	Πολλές ηλεκτρικές συσκευές (όπως τα κινητά τηλέφωνα) εκπέμπουν μεγάλη ποσότητα ακτινοβολίας όταν λειτουργούν και αυτό μπορεί να προκαλέσει προβλήματα στην υγεία των ανθρώπων. Προσπαθούμε να κατασκευάσουμε ένα όργανο που να μετρά πόση ακτινοβολία εκπέμπεται από τις διάφορες συσκευές.			
29.	Μια από τις σοβαρότερες ασθένειες που αντιμετωπίζει ο άνθρωπος, η οποία πολύ συχνά προκαλεί και το θάνατο, είναι ο καρκίνος. Προσπαθούμε να συνθέσουμε μια ουσία η οποία να λειτουργεί ως φάρμακο για αυτή την ασθένεια.			
30.	Καταγράφουμε τον αριθμό των ατόμων που εισάγονται κάθε χρόνο σε νοσοκομεία της χώρας μας με καρδιακά προβλήματα.			
31.	Υπάρχουν αρκετοί που πιστεύουν ότι η καφεΐνη βλάπτει την υγεία μας. Αυτό όμως δεν έχει μελετηθεί ακόμη αρκετά. Εμείς προσπαθούμε να το διερευνήσουμε ώστε, εάν ισχύει, να εξηγήσουμε με ποιο ακριβώς τρόπο βλάπτει την υγεία μας.			
32.	Πολλές φορές το πόσιμο νερό περιέχει ουσίες που είναι βλαβερές για την υγεία μας. Προσπαθούμε να βρούμε τρόπο να τις αφαιρούμε.			

<u>Ερώτηση</u>: Σχετικά με τις πιο πάνω απαντήσεις που έδωσες, πώς αποφάσιζες ότι ο στόχος των ερευνητών ταιριάζει με το στόχο της **επιστήμης** ή με το στόχο της **τεχνολογίας**;

<u>Απάντηση</u>:____

Ονοματεπώνυμο: ____ Τάξη: _____ Ημερ/νία: ___________

Πιο κάτω βλέπεις δηλώσεις διαφόρων ερευνητών που εξηγούν τι προσπαθούν να κάνουν στην έρευνά τους. Για τον κάθε ερευνητή σημείωσε ✓ στο κουτάκι που ταιριάζει καλύτερα.

		Προσπαθούν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος.	**Προσπαθούν να βρουν τρόπους ώστε να λύσουν κάποιο πρόβλημα ή να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας.**	**Δεν τους ενδιαφέρει ούτε η λειτουργία του φυσικού κόσμου ούτε η επίλυση προβλημάτων της ανθρωπότητας**
1.	Προσπαθούμε να σχεδιάσουμε αεροπλάνα γρηγορότερα από αυτά που έχουμε σήμερα.			
2.	Προσπαθούμε να εξηγήσουμε πώς ακριβώς δημιουργείται ο κεραυνός.			
3.	Προσπαθούμε να παρατηρήσουμε με το τηλεσκόπιο τους πλανήτες για να εξακριβώσουμε πώς κινούνται.			
4.	Ψάχνουμε να βρούμε τον καλύτερο τρόπο για να μετρούμε με ακρίβεια την ταχύτητα του ανέμου.			
5.	Εμείς έχουμε εντοπίσει πρόσφατα ένα νέο είδος οργανισμού στο πάρκο της Αγλαντζιάς και το μελετούμε ώστε να δούμε σε τι διαφέρει από τους υπόλοιπους οργανισμούς που ζουν εκεί.			
6.	Προσπαθούμε να φτιάξουμε φίλτρα που θα απορροφούν τα βλαβερά καυσαέρια που εκπέμπονται από τα φουγάρα των εργοστασίων .			
7.	Τώρα που γνωρίζουμε αρκετά πράγματα για τον τρόπο με τον οποίο συμπεριφέρονται κάποιοι ιοί όταν προσβάλουν τον ανθρώπινο οργανισμό, προσπαθούμε να δημιουργήσουμε ένα εμβόλιο που θα τους καταπολεμά.			
8.	Θέλουμε να κατανοήσουμε τι προκαλεί τους ανεμοστρόβιλους.			
9.	Προσπαθούμε να βελτιώσουμε τα μικροσκόπια ώστε να μπορούμε να κάνουμε πιο λεπτομερείς παρατηρήσεις.			
10.	Προσπαθούμε να κατανοήσουμε τη συμπεριφορά μικροσκοπικών οργανισμών που ζουν στη λίμνη της Αθαλάσσας.			
11.	Προσπαθούμε να φτιάξουμε κατασκευές που θα μας προστατεύουν από τους κεραυνούς.			
12.	Προσπαθούμε να εξετάσουμε πώς θα επηρεάζονταν οι καιρικές συνθήκες αν έλιωναν οι παγετώνες.			

		Προσπαθούν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος.	**Προσπαθούν να βρουν τρόπους ώστε να λύσουν κάποιο πρόβλημα ή να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας.**	**Δεν τους ενδιαφέρει ούτε η λειτουργία του φυσικού κόσμου ούτε η επίλυση προβλημάτων της ανθρωπότητας.**
13.	Οι πρώτες ύλες για την παραγωγή ηλεκτρισμού είναι το πετρέλαιο και το κάρβουνο. Οι ποσότητες αυτών των ουσιών στον πλανήτη μειώνονται συνεχώς και εμείς προσπαθούμε να βρούμε άλλους τρόπους παραγωγής ηλεκτρισμού.			
14.	Τα αυτοκίνητα εκπέμπουν πολλά βλαβερά αέρια προς την ατμόσφαιρα. Κάνουμε πειράματα με τη μηχανή του αυτοκίνητου στο εργαστήριό μας, ώστε να βρούμε τρόπο να μειώσουμε αυτά τα αέρια.			
15.	Προσπαθούμε να βρούμε τι είναι αυτό που προκαλεί το τσουνάμι.			
16.	Προσπαθούμε να μελετήσουμε τους παράγοντες που προκαλούν διάφορους τύπους καρκίνου.			
17.	Εμείς παίρνουμε μετρήσεις του νερού που ρέει στα φράγματα κάθε μήνα.			
18.	Προσπαθούμε να τροποποιήσουμε κάποια τρόφιμα, ώστε να βάλουμε σε αυτά ουσίες που βοηθούν στη θεραπεία διαφόρων ασθενειών.			
19.	Προσπαθούμε να προβλέψουμε πώς θα αλλάξει (αν θα αλλάξει) το κλίμα στη γη στα επόμενα πεντακόσια χρόνια. Επειδή υπάρχουν κάποιοι πολύπλοκοι μαθηματικοί υπολογισμοί χρησιμοποιούμε ηλεκτρονικούς υπολογιστές, ώστε να τους κάνουμε εύκολα και γρήγορα.			
20.	Ερευνούμε με ποιο τρόπο επηρεάζει το δέρμα μας η ηλιακή ακτινοβολία.			
21.	Προσπαθούμε να φτιάξουμε ένα όργανο μέτρησης, το οποίο θα μας βοηθά να προβλέπουμε πότε θα συμβεί ένας σεισμός και πόσο ισχυρός θα είναι.			
22.	Προσπαθούμε να φτιάξουμε υλικά οικοδομής τα οποία να είναι πιο ανθεκτικά σε σεισμούς.			
23.	Εμείς προσπαθούμε να αποφασίσουμε ποιος είναι ο καταλληλότερος χώρος για κατασκευή μονάδας αφαλάτωσης θαλασσινού νερού.			
24.	Πρόσφατα έχει γίνει ένα αυτοκινητιστικό δυστύχημα και τώρα γίνεται έρευνα για να βρεθούν οι λόγοι που οδήγησαν σε αυτό.			
25.	Μερικές φορές στενεύουν οι αρτηρίες που τροφοδοτούν την καρδιά με οξυγόνο και αυτό προκαλεί τα καρδιακά εμφράγματα. Προσπαθούμε να εξετάσουμε πώς το κάπνισμα οδηγεί στη στένωση των αρτηριών.			

		Προσπαθούν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος.	Προσπαθούν να βρουν τρόπους ώστε να λύσουν κάποιο πρόβλημα ή να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας.	Δεν τους ενδιαφέρει ούτε η λειτουργία του φυσικού κόσμου ούτε η επίλυση προβλημάτων της ανθρωπότητας
26.	Τα αντιβιοτικά φάρμακα βοηθούν στην αντιμετώπιση κάποιων ασθενειών. Όμως η πολύ συχνή χρήση αυτών των φαρμάκων φαίνεται ότι δημιουργεί νέα προβλήματα στον οργανισμό μας. Προσπαθούμε να κατανοήσουμε καλύτερα τι είδους προβλήματα προκαλεί.			
27.	Εξετάζουμε κατά πόσο οι φούρνοι μικροκυμάτων είναι επικίνδυνοι για την υγεία μας και επίσης τι είδους προβλήματα μπορεί να δημιουργούν.			
28.	Πολλές ηλεκτρικές συσκευές (όπως τα κινητά τηλέφωνα) εκπέμπουν μεγάλη ποσότητα ακτινοβολίας όταν λειτουργούν και αυτό μπορεί να προκαλέσει προβλήματα στην υγεία των ανθρώπων. Προσπαθούμε να κατασκευάσουμε ένα όργανο που να μετρά πόση ακτινοβολία εκπέμπεται από τις διάφορες συσκευές.			
29.	Μια από τις σοβαρότερες ασθένειες που αντιμετωπίζει ο άνθρωπος, η οποία πολύ συχνά προκαλεί και το θάνατο, είναι ο καρκίνος. Προσπαθούμε να συνθέσουμε μια ουσία η οποία να λειτουργεί ως φάρμακο για αυτή την ασθένεια.			
30.	Καταγράφουμε τον αριθμό των ατόμων που εισάγονται κάθε χρόνο σε νοσοκομεία της χώρας μας με καρδιακά προβλήματα.			
31.	Υπάρχουν αρκετοί που πιστεύουν ότι η καφεΐνη βλάπτει την υγεία μας. Αυτό όμως δεν έχει μελετηθεί ακόμη αρκετά. Εμείς προσπαθούμε να το διερευνήσουμε ώστε, εάν ισχύει, να εξηγήσουμε με ποιο ακριβώς τρόπο βλάπτει την υγεία μας.			
32.	Πολλές φορές το πόσιμο νερό περιέχει ουσίες που είναι βλαβερές για την για την υγεία μας. Προσπαθούμε να βρούμε τρόπο να τις αφαιρούμε.			

Appendix C

Formal Terminology test

Name: ____ Class: _______ Date: __________

Below there are some statements that describe what different researchers are trying to do in their research. For each research tick ✓ **ONE** box, which you consider as the most appropriate, i.e., whether you consider that the research fits in **science**, **technology** or **neither** of the two fields**.**

		What the researchers are trying to do belongs to science.	**What the researchers are trying to do belongs to technology.**	**What the researchers are trying to does not belong neither science nor technology**
2.	We try to explain how lightning is created.			
3.	We observe the sky through telescopes in order to study the motion of planets.			
4.	We are searching to find the best way to measure with accuracy the speed of the wind.			
7.	We try to create a vaccine against various dangerous viruses.			
10.	We try to understand the behaviour of small species that live in Athalassa lake.			
11.	We try to make an artefact that will protect us from lightning.			
12.	We try to examine how the climate conditions would change if glaciers melted.			
13.	The raw materials that are normally used for producing electricity are oil and coal. The amounts of these materials are continuously reducing, so we try to find new ways of producing electricity.			
14.	We do experiments with car machines in order to find a way to reduce polluting fumes that are emitted from factory chimneys.			
16.	We try to study the factors that cause various types of cancer.			
17.	We take monthly water flow measurements of natural streams.			
18.	We try to examine whether we can modify some food, so as to add substances known for their ability to cure some diseases.			
19.	We try to predict how the climate will change in 500 years. We use computers in order to make some complicate mathematical calculations easily and fast.			

		What the researchers are trying to do belongs to <u>science</u>.	What the researchers are trying to do belongs to <u>technology</u>.	What the researchers are trying to does not belong <u>neither science nor technology</u>
23.	We are trying to decide the best location to build a desalination plant.			
24.	Recently, there has been a car accident and now a research is conducted in order to find the causes that led to it.			
25.	Some times arteries that send oxygen to the heart get narrow and this causes heart attacks. We try to examine how smoking leads to the stenosis of the arteries.			
27.	We examine whether microwave ovens are dangerous for our health and also what sort of problems they might cause.			
28.	Many electrical devices (such as mobile phones) transmit large amount of radiation when they are operating and this could cause health problems. We try to make an instrument that measures how much radiation is transmitted by various devices.			
29.	We are trying to develop a substance that acts against known viruses linked to cancer.			
31.	Many people argue that caffeine is bad for our health. This issue has not been studied much so far. We are trying to investigate, so that we can explain how exactly it affects our health.			
32.	In many cases, drinkable water contains substances that are bad for our health. We try to find a way to remove them.			

<u>Question</u>: Concerning your responses in the above table, how do you decide whether a research project fits with the goal of **science** or **technology** or **neither**?

<u>Answer:</u> ____

____

____

____

____

Elaborated Definitions test

Name: ____ Class: _________ Date: ____________

Below there are some statements that describe what different researchers are trying to do in their research. For each research tick ✓ ONE box which in your opinion fits better.

		They try to understand better how natural world functions.	**They try to develop solutions to problems encountered by society and to meet human needs.**	**Neither of the two previous goals interests them.**
2.	We try to explain how lightning is created.			
3.	We observe the sky through telescopes in order to study the motion of planets.			
4.	We are searching to find the best way to measure with accuracy the speed of the wind.			
7.	We try to create a vaccine against various dangerous viruses.			
10.	We try to understand the behaviour of small species that live in Athalassa lake.			
11.	We try to make an artefact that will protect us from lightning.			
12.	We try to examine how the climate conditions would change if glaciers melted.			
13.	The raw materials that are normally used for producing electricity are oil and coal. The amounts of these materials are continuously reducing, so we try to find new ways of producing electricity.			
14.	We do experiments with car machines in order to find a way to reduce polluting fumes that are emitted from factory chimneys.			
16.	We try to study the factors that cause various types of cancer.			
17.	We take monthly water flow measurements of natural streams.			
18.	We try to examine whether we can modify some food, so as to add substances known for their ability to cure some diseases.			
19.	We try to predict how the climate will change in 500 years. We use computers in order to make some complicate mathematical calculations easily and fast.			

		They try to understand better how natural world functions.	They try to develop solutions to problems encountered by society and to meet human needs.	Neither of the two previous goals interests them.
23.	We are trying to decide the best location to build a desalination plant.			
24.	Recently, there has been a car accident and now a research is conducted in order to find the causes that led to it.			
25.	Some times arteries that send oxygen to the heart get narrow and this causes heart attacks. We try to examine how smoking leads to the stenosis of the arteries.			
27.	We examine whether microwave ovens are dangerous for our health and also what sort of problems they might cause.			
28.	Many electrical devices (such as mobile phones) transmit large amount of radiation when they are operating and this could cause health problems. We try to make an instrument that measures how much radiation is transmitted by various devices.			
29.	We are trying to develop a substance that acts against known viruses linked to cancer.			
31.	Many people argue that caffeine is bad for our health. This issue has not been studied much so far. We are trying to investigate, so that we can explain how exactly it affects our health.			
32.	In many cases, drinkable water contains substances that are bad for our health. We try to find a way to remove them.			

Ονοματεπώνυμο: ___________________________________ Τάξη: _____ Ημερ/νία: __________

Πιο κάτω βλέπεις δηλώσεις διαφόρων ερευνητών που εξηγούν τι προσπαθούν να κάνουν στην έρευνά τους. Για τον κάθε ερευνητή σημείωσε ✓ σε <u>ΕΝΑ</u> κουτάκι ανάλογα με το κατά πόσο θεωρείς ότι αυτό που κάνει ταιριάζει με τον στόχο της **επιστήμης**, της **τεχνολογίας** ή με **κανένα** από τους δύο κλάδους**.**

		Ο στόχος των ερευνητών ταιριάζει με το <u>στόχο της επιστήμης.</u>	**Ο στόχος των ερευνητών ταιριάζει με τον <u>στόχο της τεχνολογίας.</u>**	**Ο στόχος των ερευνητών δεν ταιριάζει <u>ούτε με το στόχο της επιστήμης ούτε με το στόχο της τεχνολογίας.</u>**
2.	Προσπαθούμε να εξηγήσουμε πώς ακριβώς δημιουργείται ο κεραυνός.			
3.	Προσπαθούμε να παρατηρήσουμε με το τηλεσκόπιο τους πλανήτες για να εξακριβώσουμε πώς κινούνται.			
4.	Ψάχνουμε να βρούμε τον καλύτερο τρόπο για να μετρούμε με ακρίβεια την ταχύτητα του ανέμου			
7.	Προσπαθούμε να δημιουργήσουμε ένα εμβόλιο που να καταπολεμά διάφορους επικίνδυνους ιούς.			
10.	Προσπαθούμε να κατανοήσουμε τη συμπεριφορά μικροσκοπικών οργανισμών που ζουν στη λίμνη της Αθαλάσσας.			
11.	Προσπαθούμε να φτιάξουμε κατασκευές που θα μας προστατεύουν από τους κεραυνούς.			
12.	Προσπαθούμε να εξετάσουμε πώς θα επηρεάζονταν οι καιρικές συνθήκες αν έλιωναν οι παγετώνες.			
13.	Οι πρώτες ύλες για την παραγωγή ηλεκτρισμού είναι το πετρέλαιο και το κάρβουνο. Οι ποσότητες αυτών των ουσιών στον πλανήτη μειώνονται συνεχώς και εμείς προσπαθούμε να βρούμε άλλους τρόπους παραγωγής ηλεκτρισμού.			
14.	Τα αυτοκίνητα εκπέμπουν πολλά βλαβερά αέρια προς την ατμόσφαιρα. Κάνουμε πειράματα με τη μηχανή του αυτοκίνητου στο εργαστήριό μας, ώστε να βρούμε τρόπο να μειώσουμε αυτά τα αέρια.			
16.	Προσπαθούμε να μελετήσουμε τους παράγοντες που προκαλούν διάφορους τύπους καρκίνου.			
17.	Εμείς παίρνουμε μετρήσεις του νερού που ρέει στα φράγματα κάθε μήνα.			
18.	Προσπαθούμε να εξετάσουμε κατά πόσο μπορούμε να τροποποιήσουμε κάποια τρόφιμα, ώστε να βάλουμε σε αυτά ουσίες που βοηθούν στη θεραπεία διαφόρων ασθενειών.			
19.	Προσπαθούμε να προβλέψουμε πώς θα αλλάξει (αν θα αλλάξει) το κλίμα στη γη στα επόμενα πεντακόσια χρόνια. Επειδή υπάρχουν κάποιοι πολύπλοκοι μαθηματικοί υπολογισμοί χρησιμοποιούμε ηλεκτρονικούς υπολογιστές, ώστε να τους κάνουμε εύκολα και γρήγορα.			

		Ο στόχος των ερευνητών ταιριάζει με το στόχο της επιστήμης.	**Ο στόχος των ερευνητών ταιριάζει με τον στόχο της τεχνολογίας.**	**Ο στόχος των ερευνητών δεν ταιριάζει ούτε με το στόχο της επιστήμης ούτε με το στόχο της τεχνολογίας.**
23.	Εμείς προσπαθούμε να αποφασίσουμε ποιος είναι ο καταλληλότερος χώρος για κατασκευή μονάδας αφαλάτωσης θαλασσινού νερού.			
24.	Πρόσφατα έχει γίνει ένα αυτοκινητιστικό δυστύχημα και τώρα γίνεται έρευνα για να βρεθούν οι λόγοι που οδήγησαν σε αυτό.			
25.	Μερικές φορές στενεύουν οι αρτηρίες που τροφοδοτούν την καρδιά με οξυγόνο και αυτό προκαλεί τα καρδιακά εμφράγματα. Προσπαθούμε να εξετάσουμε πώς το κάπνισμα οδηγεί στη στένωση των αρτηριών.			
27.	Εξετάζουμε κατά πόσο οι φούρνοι μικροκυμάτων είναι επικίνδυνοι για την υγεία μας και επίσης τι είδους προβλήματα μπορεί να δημιουργούν.			
28.	Πολλές ηλεκτρικές συσκευές (όπως τα κινητά τηλέφωνα) εκπέμπουν μεγάλη ποσότητα ακτινοβολίας όταν λειτουργούν και αυτό μπορεί να προκαλέσει προβλήματα στην υγεία των ανθρώπων. Προσπαθούμε να κατασκευάσουμε ένα όργανο που να μετρά πόση ακτινοβολία εκπέμπεται από τις διάφορες συσκευές.			
29.	Μια από τις σοβαρότερες ασθένειες που αντιμετωπίζει ο άνθρωπος, η οποία πολύ συχνά προκαλεί και το θάνατο, είναι ο καρκίνος. Προσπαθούμε να συνθέσουμε μια ουσία η οποία να λειτουργεί ως φάρμακο για αυτή την ασθένεια.			
31.	Υπάρχουν αρκετοί που πιστεύουν ότι η καφεΐνη βλάπτει την υγεία μας. Αυτό όμως δεν έχει μελετηθεί ακόμη αρκετά. Εμείς προσπαθούμε να το διερευνήσουμε ώστε, εάν ισχύει, να εξηγήσουμε με ποιο ακριβώς τρόπο βλάπτει την υγεία μας.			
32.	Πολλές φορές το πόσιμο νερό περιέχει ουσίες που είναι βλαβερές για την υγεία μας. Προσπαθούμε να βρούμε τρόπο να τις αφαιρούμε.			

Ερώτηση: Σχετικά με τις πιο πάνω απαντήσεις που έδωσες, πώς αποφάσιζες ότι ο στόχος των ερευνητών ταιριάζει με το στόχο της **επιστήμης** ή με το στόχο της **τεχνολογίας**;

Απάντηση: ____

____

____

Ονοματεπώνυμο: ____ Τάξη: _____ Ημερ/νία: _________

Πιο κάτω βλέπεις δηλώσεις διαφόρων ερευνητών που εξηγούν τι προσπαθούν να κάνουν στην έρευνά τους. Για τον κάθε ερευνητή σημείωσε ✓ στο κουτάκι που ταιριάζει καλύτερα.

		Προσπαθούν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος.	**Προσπαθούν να βρουν τρόπους ώστε να λύσουν κάποιο πρόβλημα ή να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας.**	**Δεν τους ενδιαφέρει ούτε η λειτουργία του φυσικού κόσμου ούτε η επίλυση προβλημάτων της ανθρωπότητας.**
2.	Προσπαθούμε να εξηγήσουμε πώς ακριβώς δημιουργείται ο κεραυνός			
3.	Προσπαθούμε να παρατηρήσουμε με το τηλεσκόπιο τους πλανήτες για να εξακριβώσουμε πώς κινούνται			
4.	Ψάχνουμε να βρούμε τον καλύτερο τρόπο για να μετρούμε με ακρίβεια την ταχύτητα του ανέμου			
7.	Προσπαθούμε να δημιουργήσουμε ένα εμβόλιο που να καταπολεμά διάφορους επικίνδυνους ιούς.			
10.	Προσπαθούμε να κατανοήσουμε τη συμπεριφορά μικροσκοπικών οργανισμών που ζουν στη λίμνη της Αθαλάσσας.			
11.	Προσπαθούμε να φτιάξουμε κατασκευές που θα μας προστατεύουν από τους κεραυνούς.			
12.	Προσπαθούμε να εξετάσουμε πώς θα επηρεάζονταν οι καιρικές συνθήκες αν έλιωναν οι παγετώνες			
13.	Οι πρώτες ύλες για την παραγωγή ηλεκτρισμού είναι το πετρέλαιο και το κάρβουνο. Οι ποσότητες αυτών των ουσιών στον πλανήτη μειώνονται συνεχώς και εμείς προσπαθούμε να βρούμε άλλους τρόπους παραγωγής ηλεκτρισμού.			
14.	Τα αυτοκίνητα εκπέμπουν πολλά βλαβερά αέρια προς την ατμόσφαιρα. Κάνουμε πειράματα με τη μηχανή του αυτοκίνητου στο εργαστήριό μας, ώστε να βρούμε τρόπο να μειώσουμε αυτά τα αέρια.			
16.	Προσπαθούμε να μελετήσουμε τους παράγοντες που προκαλούν διάφορους τύπους καρκίνου.			
17.	Εμείς παίρνουμε μετρήσεις του νερού που ρέει στα φράγματα κάθε μήνα.			
18.	Προσπαθούμε να εξετάσουμε κατά πόσο μπορούμε να τροποποιήσουμε κάποια τρόφιμα, ώστε να βάλουμε σε αυτά ουσίες που βοηθούν στη θεραπεία διαφόρων ασθενειών.			

		Προσπαθούν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος.	**Προσπαθούν να βρουν τρόπους ώστε να λύσουν κάποιο πρόβλημα ή να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας.**	**Δεν τους ενδιαφέρει ούτε η λειτουργία του φυσικού κόσμου ούτε η επίλυση προβλημάτων της ανθρωπότητας.**
19.	Προσπαθούμε να προβλέψουμε πώς θα αλλάξει (αν θα αλλάξει) το κλίμα στη γη στα επόμενα πεντακόσια χρόνια. Επειδή υπάρχουν κάποιοι πολύπλοκοι μαθηματικοί υπολογισμοί χρησιμοποιούμε ηλεκτρονικούς υπολογιστές, ώστε να τους κάνουμε εύκολα και γρήγορα.			
23.	Εμείς προσπαθούμε να αποφασίσουμε ποιος είναι ο καταλληλότερος χώρος για κατασκευή μονάδας αφαλάτωσης θαλασσινού νερού.			
24.	Πρόσφατα έχει γίνει ένα αυτοκινητιστικό δυστύχημα και τώρα γίνεται έρευνα για να βρεθούν οι λόγοι που οδήγησαν σε αυτό.			
25.	Μερικές φορές στενεύουν οι αρτηρίες που τροφοδοτούν την καρδιά με οξυγόνο και αυτό προκαλεί τα καρδιακά εμφράγματα. Προσπαθούμε να εξετάσουμε πώς το κάπνισμα οδηγεί στη στένωση των αρτηριών.			
27.	Εξετάζουμε κατά πόσο οι φούρνοι μικροκυμάτων είναι επικίνδυνοι για την υγεία μας και επίσης τι είδους προβλήματα μπορεί να δημιουργούν.			
28.	Πολλές ηλεκτρικές συσκευές (όπως τα κινητά τηλέφωνα) εκπέμπουν μεγάλη ποσότητα ακτινοβολίας όταν λειτουργούν και αυτό μπορεί να προκαλέσει προβλήματα στην υγεία των ανθρώπων. Προσπαθούμε να κατασκευάσουμε ένα όργανο που να μετρά πόση ακτινοβολία εκπέμπεται από τις διάφορες συσκευές.			
29.	Μια από τις σοβαρότερες ασθένειες που αντιμετωπίζει ο άνθρωπος, η οποία πολύ συχνά προκαλεί και το θάνατο, είναι ο καρκίνος. Προσπαθούμε να συνθέσουμε μια ουσία η οποία να λειτουργεί ως θεραπεία/φάρμακο για αυτή την ασθένεια.			
31.	Υπάρχουν αρκετοί που πιστεύουν ότι η καφεΐνη βλάπτει την υγεία μας. Αυτό όμως δεν έχει μελετηθεί ακόμη αρκετά. Εμείς προσπαθούμε να το διερευνήσουμε ώστε, εάν ισχύει, να εξηγήσουμε με ποιο ακριβώς τρόπο βλάπτει την υγεία μας.			
32.	Πολλές φορές το πόσιμο νερό περιέχει ουσίες που είναι βλαβερές για την για την υγεία μας. Προσπαθούμε να βρούμε τρόπο να τις αφαιρούμε.			

Appendix D: Semi-structured interview protocol used in Studies 2 and 3

Όνομα: ____ Τάξη: ______ Ημερ.: _____________

(Α) Αρχική οδηγία: Στον πίνακα που έχεις μπροστά σου υπάρχουν δηλώσεις διαφόρων ερευνητών που εξηγούν τι προσπαθούν να κάνουν στην έρευνά τους. Για κάθε μια δήλωση που θα σου διαβάζω χρειάζομαι να σκέφτεσαι κάθε φορά κατά πόσο ο στόχος των ερευνητών ταιριάζει περισσότερο με τον στόχο της επιστήμης, ή αν ταιριάζει περισσότερο με το στόχο της τεχνολογίας ή με κανένα από τους δύο κλάδους. Όταν επιλέγεις θέλω να μου εξηγείς και πώς το σκέφτηκες.

Καθώς απαντούν:

- Πώς το σκέφτηκες; Γιατί επέλεξες επιστήμη και όχι τεχνολογία; Γιατί επέλεξες τεχνολογία και όχι επιστήμη; Γιατί απέρριψες το ένα και γιατί το άλλο; Εξήγα μου γιατί το Χ. Όταν λες «…» τι εννοείς;
- Αν θεωρούν ότι εμπίπτει και στα δύο, να μας εξηγούν γιατί το ένα και γιατί το άλλο και μετά να τους ζητούμε να επιλέξουν αυτό που θεωρούν ότι ταιριάζει περισσότερο.
- Αν εντοπίζουμε ασυνέπειες να τις επισημαίνουμε και να ζητούμε επεξήγηση.

		Ο στόχος των ερευνητών ταιριάζει με το στόχο της επιστήμης.	**Ο στόχος των ερευνητών ταιριάζει με τον στόχο της τεχνολογίας.**	**Ο στόχος των ερευνητών δεν ταιριάζει ούτε με το στόχο της επιστήμης ούτε με το στόχο της τεχνολογίας.**
7.	Τώρα που γνωρίζουμε αρκετά πράγματα για τον τρόπο με τον οποίο συμπεριφέρονται κάποιοι ιοί όταν προσβάλουν τον ανθρώπινο οργανισμό, προσπαθούμε να δημιουργήσουμε ένα εμβόλιο που θα τους καταπολεμά.			
14.	Τα αυτοκίνητα εκπέμπουν πολλά βλαβερά αέρια προς την ατμόσφαιρα. Κάνουμε πειράματα με τη μηχανή του αυτοκίνητου στο εργαστήριό μας ώστε να βρούμε τρόπο να μειώσουμε αυτά τα αέρια.			
18.	Προσπαθούμε να τροποποιήσουμε κάποια τρόφιμα, ώστε να βάλουμε σε αυτά ουσίες που βοηθούν στη θεραπεία διαφόρων ασθενειών.			
19.	Προσπαθούμε να προβλέψουμε πώς θα αλλάξει (αν θα αλλάξει) το κλίμα στη γη στα επόμενα πεντακόσια χρόνια. Επειδή υπάρχουν κάποιοι πολύπλοκοι μαθηματικοί υπολογισμοί χρησιμοποιούμε ηλεκτρονικούς υπολογιστές ώστε να τους κάνουμε εύκολα και γρήγορα.			
23.	Εμείς προσπαθούμε να αποφασίσουμε ποιος είναι ο καταλληλότερος χώρος για κατασκευή μονάδας αφαλάτωσης θαλασσινού νερού.			
27.	Εξετάζουμε κατά πόσο οι φούρνοι μικροκυμάτων είναι επικίνδυνοι για την υγεία μας και επίσης τι είδους προβλήματα μπορεί να δημιουργούν.			

29.	Μια από τις σοβαρότερες ασθένειες που αντιμετωπίζει ο άνθρωπος, η οποία πολύ συχνά προκαλεί και το θάνατο, είναι ο καρκίνος. Προσπαθούμε να συνθέσουμε μια ουσία η οποία να λειτουργεί ως φάρμακο για αυτή την ασθένεια.			
32.	Πολλές φορές το πόσιμο νερό περιέχει ουσίες που είναι βλαβερές για την για την υγεία μας. Προσπαθούμε να βρούμε τρόπο να τις αφαιρούμε.			

(Β) Γενικότερα, πότε αποφασίζεις ότι ο στόχος των ερευνητών ταιριάζει με το στόχο της <u>επιστήμης</u> ή με το στόχο της <u>τεχνολογίας</u> ή με κανένα από τα δύο;

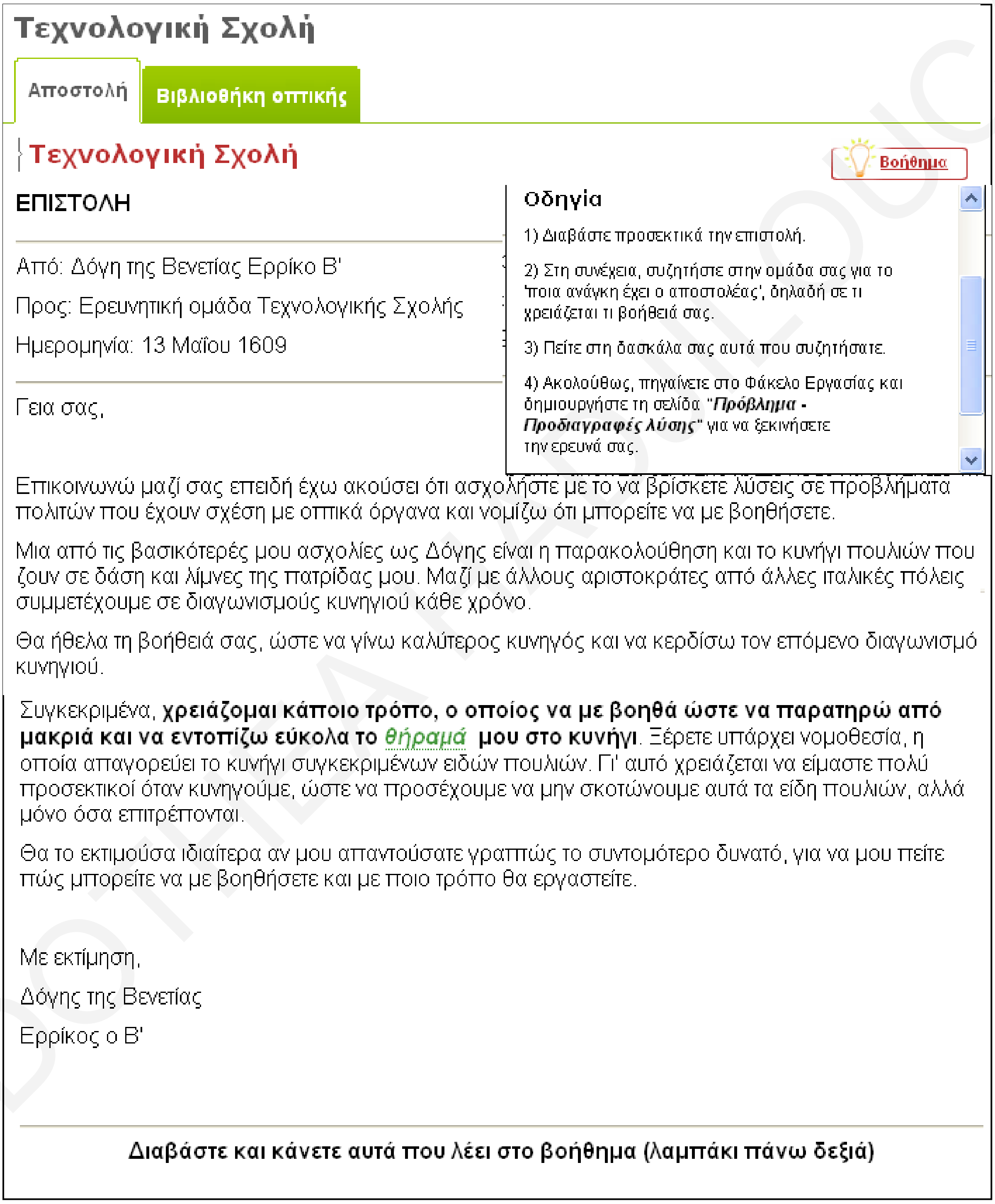
(Γ) Θα σου διαβάσω και πάλι κάποιες δηλώσεις στις οποίες αναφέρεται ο στόχος ορισμένων ερευνών. Αυτή τη φορά, όμως, για κάθε μια δήλωση που θα σου διαβάζω χρειάζομαι να σκεφτείς κατά πόσο οι ερευνητές θέλουν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος, ή κατά πόσο προσπαθούν να βρουν τρόπους ώστε να λυθεί κάποιο πρόβλημα και να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας, ή κανένα από τα δύο. Όταν επιλέγεις θέλω να μου εξηγείς και πώς το σκέφτηκες.

5 δηλώσεις (1-3-1)		**Προσπαθούν να καταλάβουν πώς λειτουργεί ο φυσικός κόσμος.**	**Προσπαθούν να βρουν τρόπους ώστε να λύσουν κάποιο πρόβλημα ή να ικανοποιήσουν κάποιες ανάγκες της ανθρωπότητας.**	**Δεν τους ενδιαφέρει ούτε η λειτουργία του φυσικού κόσμου ούτε η επίλυση προβλημάτων της ανθρωπότητας.**
18.	Προσπαθούμε να τροποποιήσουμε κάποια τρόφιμα, ώστε να βάλουμε σε αυτά ουσίες που βοηθούν στη θεραπεία διαφόρων ασθενειών.			
32.	Πολλές φορές το πόσιμο νερό περιέχει ουσίες που είναι βλαβερές για την για την υγεία μας. Προσπαθούμε να βρούμε τρόπο να τις αφαιρούμε.			
29.	Μια από τις σοβαρότερες ασθένειες που αντιμετωπίζει ο άνθρωπος, η οποία πολύ συχνά προκαλεί και το θάνατο, είναι ο καρκίνος. Προσπαθούμε να συνθέσουμε μια ουσία η οποία να λειτουργεί ως φάρμακο για αυτή την ασθένεια.			
27.	Εξετάζουμε κατά πόσο οι φούρνοι μικροκυμάτων είναι επικίνδυνοι για την υγεία μας και επίσης τι είδους προβλήματα μπορεί να δημιουργούν.			
23.	Εμείς προσπαθούμε να αποφασίσουμε ποιος είναι ο καταλληλότερος χώρος για κατασκευή μονάδας αφαλάτωσης θαλασσινού νερού.			

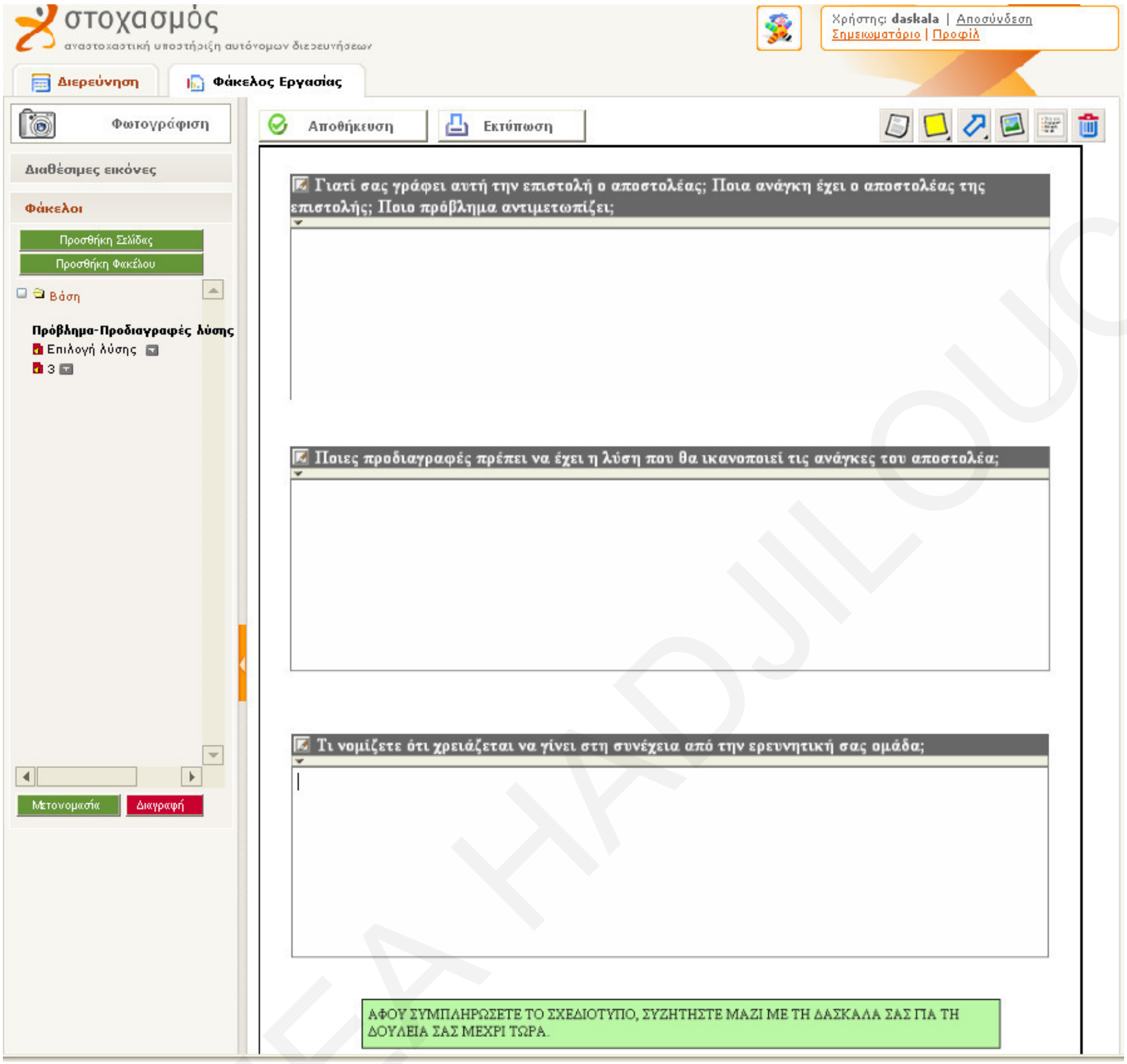
Appendix E: Teaching-Learning materials used in Study 2

Screenshots from Stochasmos platform and Worksheets

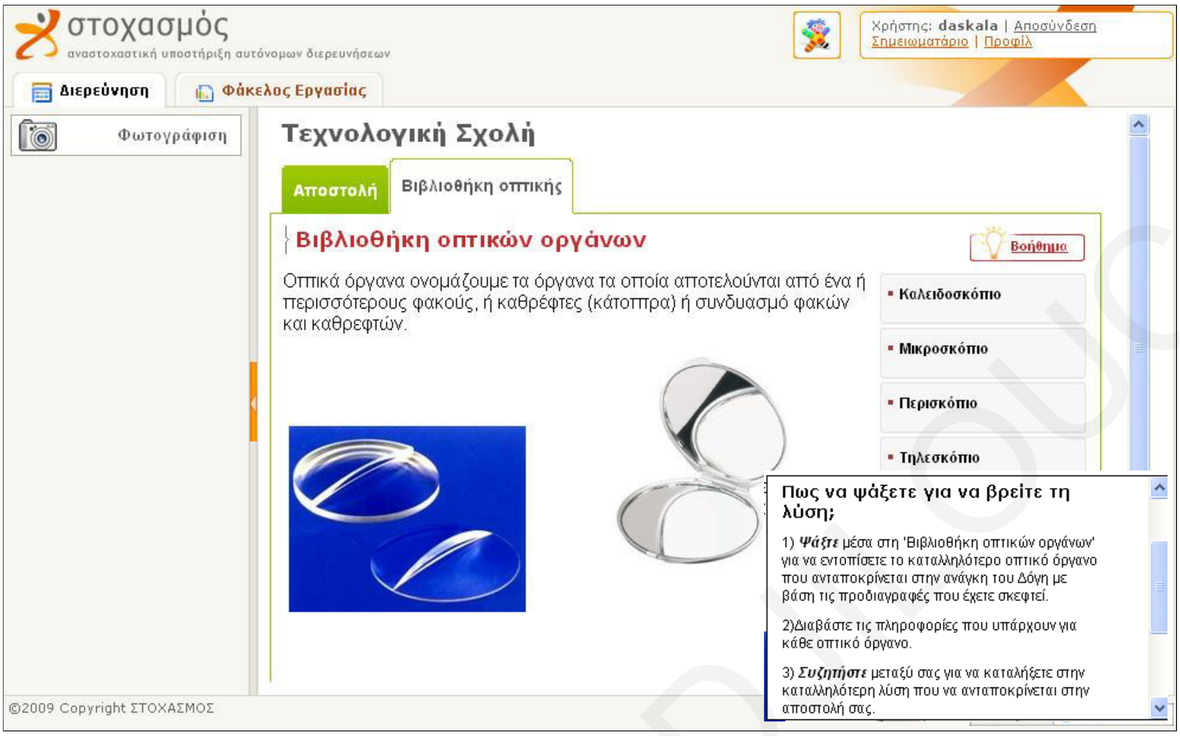
"Mission" page accompanied by a "hint on demand"



Worksheet "Problem statement, formulation of the solution's specifications, next steps"



Introductory page of the "Optics library" accompanied by a "hint on demand"

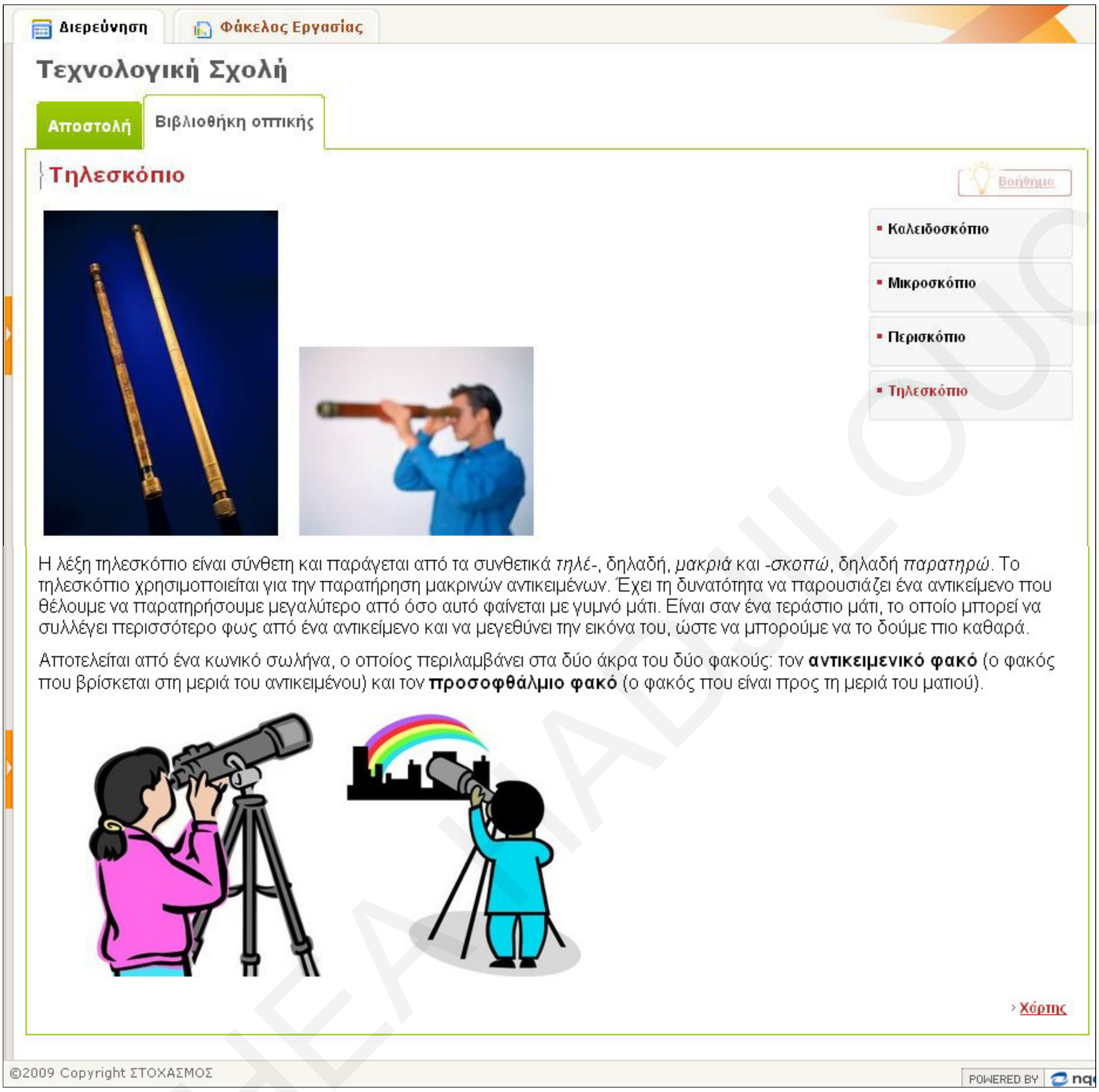


Page from the "Optics library" (kaleidoscope)

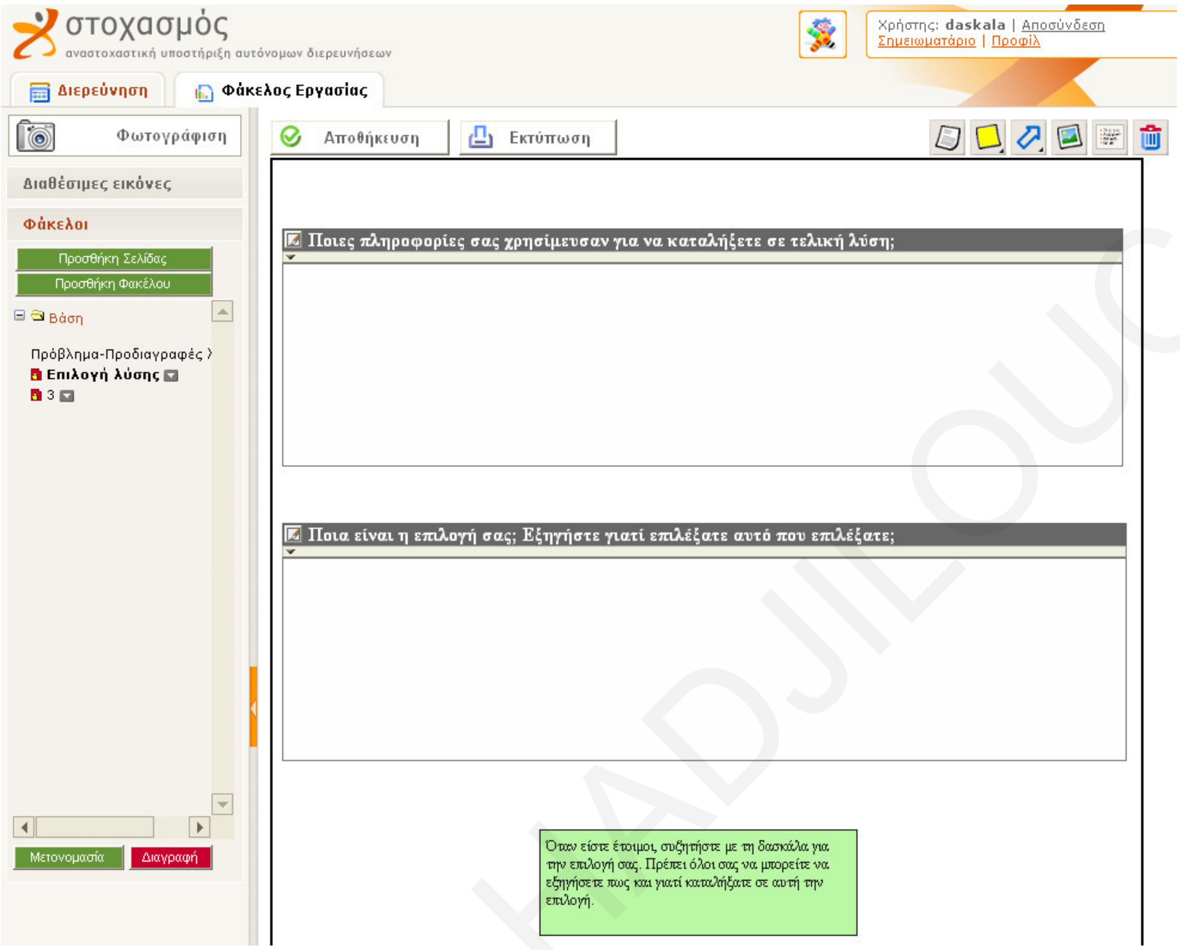
Page from the "Optics library" (microscope)

Page from the "Optics library" (periscope)

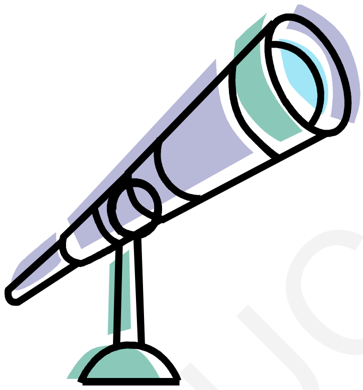
Page from the "Optics library" (telescope)



Template for choosing the best solution



Πώς να φτιάξετε ένα τηλεσκόπιο;



Προετοιμασία:

1. Προτού αρχίσετε, **διαβάστε προσεκτικά τις οδηγίες κατασκευής (Βήμα 1 – Βήμα 5)** του τηλεσκοπίου και ρωτήστε τη δασκάλα σας αν δεν καταλαβαίνετε κάτι.

2. Όταν είστε έτοιμοι να ξεκινήσετε, ένας μαθητής/τρια της ομάδας να προμηθευτεί τα απαραίτητα υλικά από την έδρα.

Υλικά που θα χρειαστείτε:

2 μεγεθυντικούς φακούς, μια μεγάλη ρίγα ή μετροταινία, 1 χάρτινο κύλινδρο

Οδηγίες κατασκευής:

Βήμα 1. Πρώτα πρέπει να εντοπίσετε την απόσταση που πρέπει να υπάρχει ανάμεσα στους δύο φακούς.

- Θυμηθείτε ότι τα τηλεσκόπια χρησιμοποιούνται για την παρατήρηση μακρινών αντικειμένων. Επομένως, χρειάζεται να εντοπίσετε και να συμφωνήσετε στην ομάδα σας ένα χώρο από τον οποίο να μπορείτε να παρατηρείτε **μακρινά αντικείμενα** για τα πειράματά σας (π.χ., κοντά σε ένα παράθυρο).
- Τοποθετήστε τον ένα φακό κοντά στο μάτι σας και τον άλλο φακό προς το μέρος του αντικειμένου που θέλετε να παρατηρήσετε. Ο φακός που είναι κοντά στο μάτι σας ονομάζεται <u>προσοφθάλμιος</u> και ο φακός που είναι προς το μέρος του αντικειμένου ονομάζεται <u>αντικειμενικός</u>.
- Κρατήστε τους δύο φακούς στην ίδια ευθεία. **Μεταβάλετε την απόσταση μεταξύ των δύο φακών, μέχρι να μπορείτε να παρατηρήσετε με ευκρίνεια μακρινά αντικείμενα και σε μέγεθος μεγαλύτερο από ότι τα βλέπετε με γυμνό μάτι**.
- Μόλις βρείτε αυτή την απόσταση ένα μέλος της ομάδας να την μετρήσει. Αν δυσκολεύεστε να βρείτε αυτή την απόσταση, ζητήστε βοήθεια από τη δασκάλα.
- Απόσταση μεταξύ των δύο φακών: ______ εκατοστόμετρα

Βήμα 2. Προμηθευτείτε από την έδρα ένα χάρτινο κύλινδρο με τόσο μήκος όση πρέπει να είναι η απόσταση ανάμεσα στους δύο φακούς την οποία μετρήσατε στο Βήμα 1.

Βήμα 3. Στερεώστε προσεκτικά πάνω στις δύο άκρες του χάρτινου κυλίνδρου τους δύο φακούς.

Βήμα 4. Χρησιμοποιώντας ένα μολύβι σχεδιάστε ένα 'μάτι' στην άκρη του σωλήνα στην οποία βρίσκεται ο προσοφθάλμιος φακός ώστε να ξέρετε από ποια πλευρά θα χρησιμοποιείτε το τηλεσκόπιό σας. (Αλήθεια υπάρχει διαφορά αν κοιτάξουμε από τη μια ή την άλλη πλευρά;)

Βήμα 5. Συγχαρητήρια! Μόλις έχετε κατασκευάσει ένα τηλεσκόπιο! Χρησιμοποιήστε το ένας-ένας για να παρατηρήσετε μακρινά αντικείμενα.

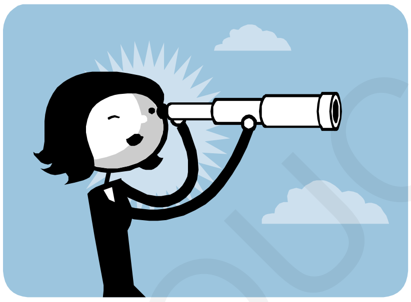
Το πρώτο πράγμα που θα έχετε ίσως παρατηρήσει είναι ότι κοιτάζοντας μέσα από το τηλεσκόπιό σας, τα αντικείμενα φαίνονται ανεστραμμένα και πολύ πιο μεγάλα από ότι όταν τα κοιτάζετε με γυμνό μάτι.

Θυμηθείτε το κριτήριό σας για να επιλέξετε το τηλεσκόπιο ως την πιο κατάλληλη λύση. Ισχύει αυτό το κριτήριο; Αν ναι, τότε η λύση σας είναι όντως κατάλληλη για τις ανάγκες του Δόγη Ερρίκου.

Μην προχωρήσετε αν δεν μιλήσετε με τη δασκάλα σχετικά με τις ερωτήσεις που υπάρχουν στο πιο πάνω κουτί.

Πόσο δυνατό είναι το τηλεσκόπιό σας;

- Συμφωνήστε με την ομάδα σας να κοιτάξετε όλοι ένα συγκεκριμένο μακρινό αντικείμενο.
- Στη συνέχεια χρησιμοποιήστε το τηλεσκόπιό σας ένας-ένας κάθε φορά για να παρατηρήσετε το μακρινό αντικείμενο το οποίο έχετε συμφωνήσει. Πρέπει όλα τα παιδιά της ομάδας να χρησιμοποιήσουν το τηλεσκόπιο.



- **Προσπαθήστε να βλέπετε ταυτόχρονα το αντικείμενο αυτό μέσα από το τηλεσκόπιο και με γυμνό μάτι!** Για να το πετύχετε αυτό, με το ένα σας μάτι να κοιτάζετε μέσα από το τηλεσκόπιο το αντικείμενο και με το άλλο σας μάτι να βλέπετε κατευθείαν το αντικείμενο.

<u>Προμηθευτείτε μια ρίγα</u>

α) Πόσο είναι το ύψος του μακρινού αντικειμένου όταν το κοιτάζετε μέσα από το τηλεσκόπιο; [Απάντηση: ____ εκατοστόμετρα]

β) Πόσο είναι το ύψος του ίδιου αντικειμένου όταν το κοιτάζετε με γυμνό μάτι; [Απάντηση: ____ εκατοστόμετρα]

γ) Συγκρίνετε την απάντησή σας στο (α) με την απάντησή σας στο (β). Τι παρατηρείτε; ____

____

δ) Διαιρέστε το ύψος που μετρήσατε στο (α) με το ύψος που μετρήσατε στο (β).
[Απάντηση: _______]

Το πηλίκο που βρήκατε στο ερώτημα (δ) αυτό ονομάζεται **μεγέθυνση του τηλεσκοπίου** και μας δείχνει πόσες φορές πιο μεγάλο φαίνεται ένα αντικείμενο όταν το κοιτάζουμε μέσα από το τηλεσκόπιο σε σύγκριση με το μέγεθος που παρατηρούμε όταν το κοιτάζουμε με γυμνό μάτι.

ε) Η μεγέθυνση του τηλεσκοπίου μας είναι ______ . Εξηγήστε τι σημαίνει αυτός ο αριθμός. ____

____

<u>Μην προχωρήσετε αν δεν μιλήσετε με τη δασκάλα, ώστε να της εξηγήσετε την απάντησή σας στην πιο πάνω ερώτηση.</u>

- Ανταλλάξτε τηλεσκόπιο με τη διπλανή ομάδα και χρησιμοποιήστε το για να παρατηρήσετε το <u>ίδιο</u> αντικείμενο που παρατηρούσατε και προηγουμένως.
- Συγκρίνετε τι παρατηρείτε όταν κοιτάζετε μέσα από αυτό το τηλεσκόπιο της άλλης ομάδας με το τι παρατηρείτε όταν κοιτάζετε μέσα από το δικό σας τηλεσκόπιο. Λειτουργούν με τον ίδιο τρόπο τα δύο τηλεσκόπια; Έχουν την ίδια μεγέθυνση; Συζητήστε το στην ομάδα σας.
- Πώς θα μπορούσατε να βελτιώσετε το τηλεσκόπιό σας;

____

____

____

____

____

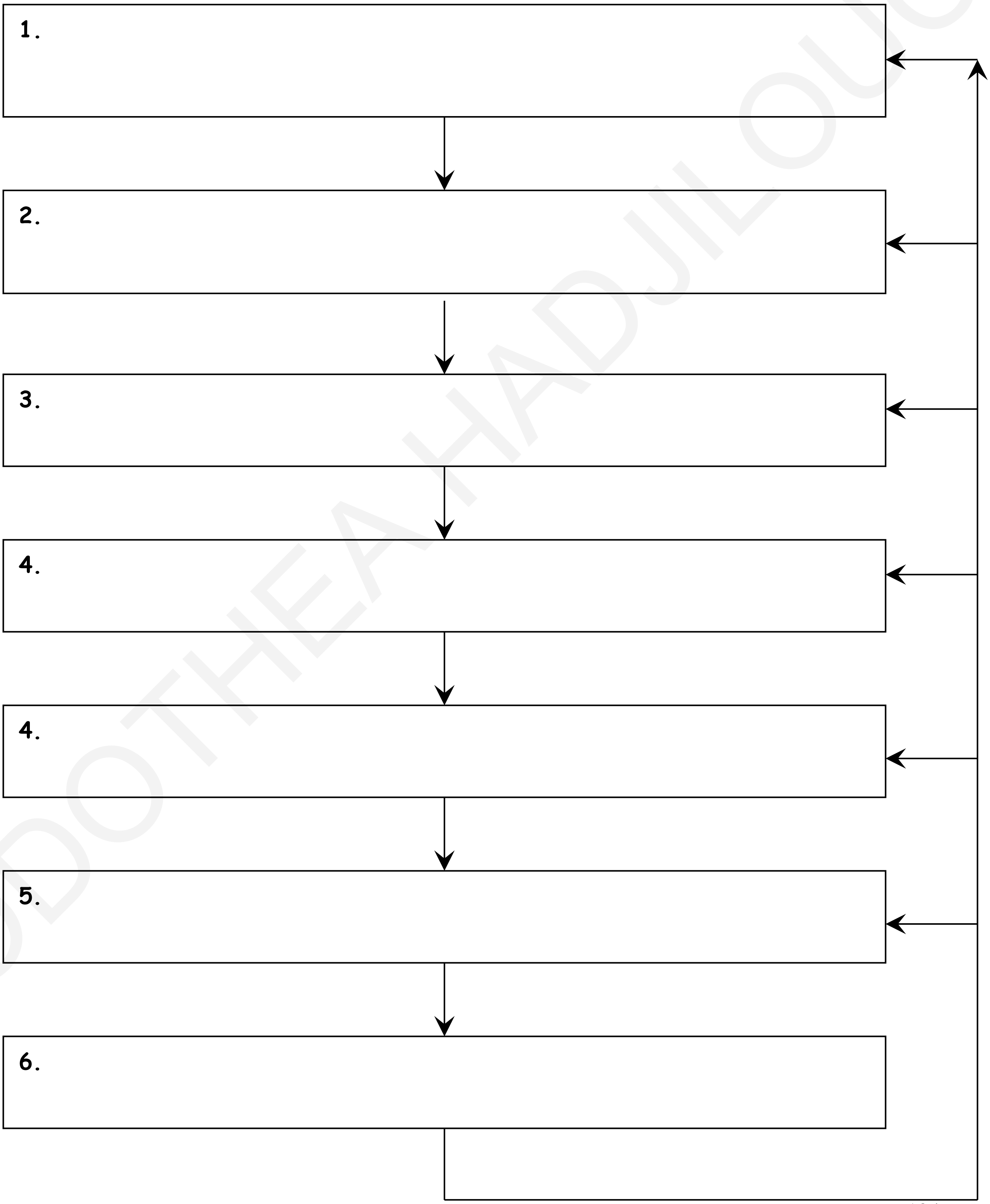
<u>Συζητήστε τις ιδέες σας με τη δασκάλα.</u>

Η αποστολή μας ήταν να ……………………………………………………………..

...……………………………………………………………………………………

……..……………………………………………………………………………….

Η ερευνητική διαδικασία που ακολουθήσαμε για να πετύχουμε την πιο πάνω αποστολή αποτελείται από τα ακόλουθα στάδια:

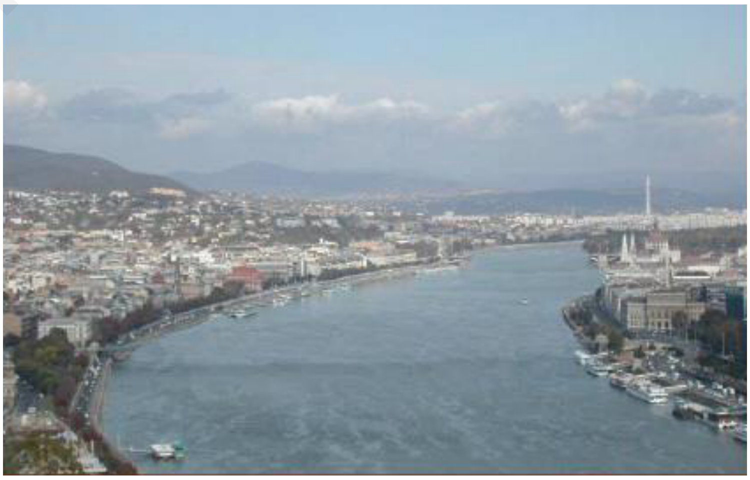


Η Βουδαπέστη είναι μια πόλη στην Ουγγαρία που χωρίζεται στη μέση από τον ποταμό Δούναβη. Στην πόλη αυτή, οι περισσότεροι κάτοικοι χρειάζονταν να ταξιδεύουν καθημερινά κατά μήκος του ποταμού για να πάνε στις δουλειές τους.

Για να λύσουν αυτό το πρόβλημα, ο δήμαρχος της πόλης ζήτησε από διάφορους ειδικούς να βρουν ένα καλό τρόπο ώστε να μπορούν οι κάτοικοι της Βουδαπέστης να κυκλοφορούν σε όλα τα μέρη της πόλης εύκολα. Οι διάφοροι ειδικοί προσπάθησαν να βρουν λύση στο πρόβλημα. Έκανε ο καθένας τις δικές του μελέτες και έψαξαν να βρουν τι έγινε σε άλλες παρόμοιες περιπτώσεις σε άλλες περιοχές που είχαν παρόμοιο πρόβλημα. Προτάθηκαν διάφορες λύσεις. Μερικές από αυτές ήταν: η κατασκευή γεφυρών, η αγορά πλοίων που να κάνουν συχνές διαδρομές από το ένα μέρος της πόλης στο άλλο κατά μήκος του ποταμού, η αγορά μικρών ιδιωτικών σκαφών, τα οποία να μπορούν να ενοικιάζουν οι πολίτες.

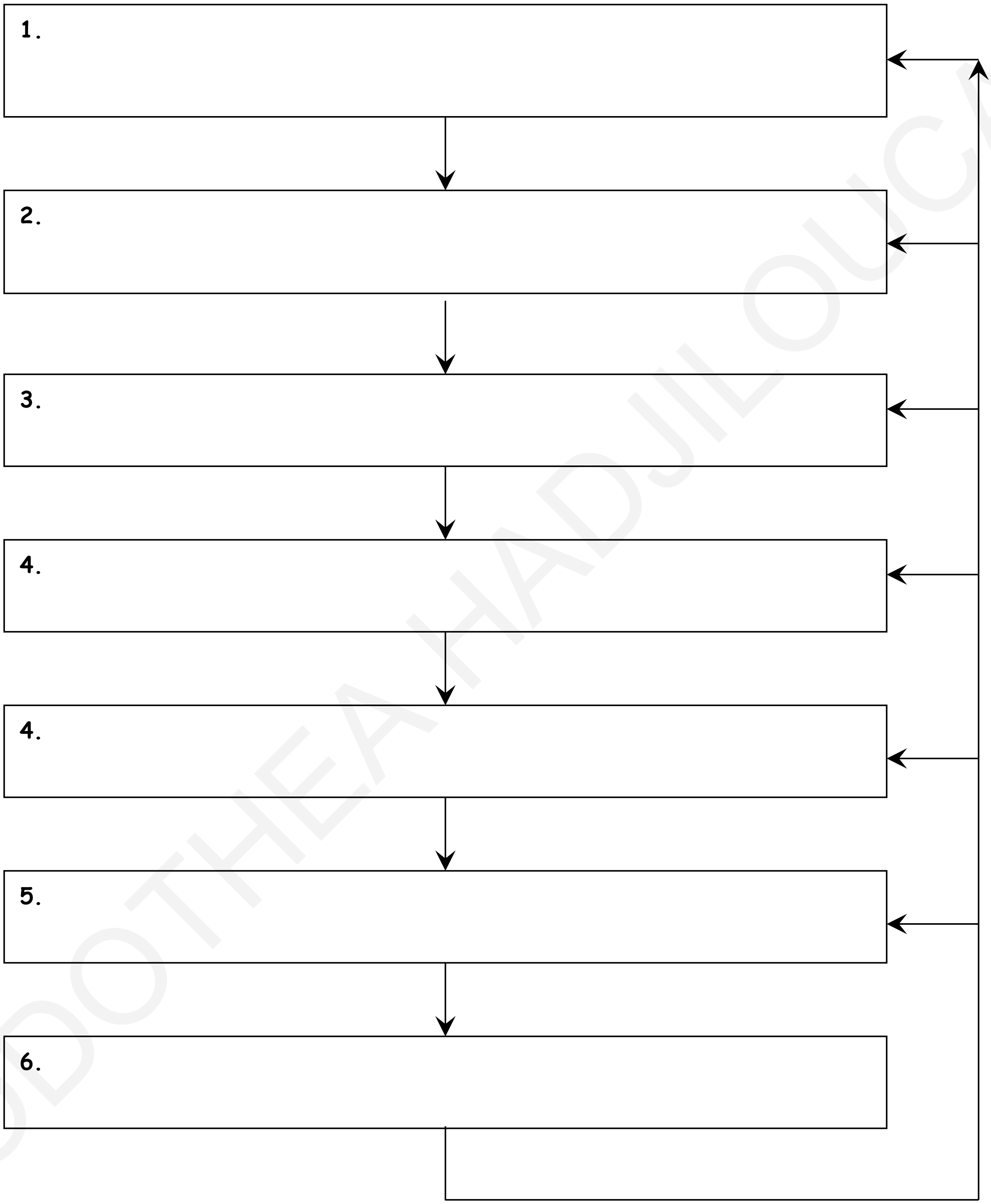
Τελικά αποφασίστηκε ότι το καλύτερο σε αυτή την περίπτωση θα ήταν να φτιάξουν μερικές γέφυρες ώστε οι κάτοικοι να μπορούν να πηγαινοέρχονται με τα αυτοκίνητά τους. Πρώτα κτίστηκε μια μόνο γέφυρα, ώστε να δουν κατά πόσο τελικά αυτό θα βοηθούσε τους πολίτες. Πράγματι, πολλοί πολίτες τώρα μπορούσαν να διακινούνται σε όλη την πόλη χρησιμοποιώντας ιδιωτικά αυτοκίνητα ή τα δημόσια λεωφορεία.

Μετά από πολλά χρόνια όμως όταν κατασκευάστηκαν μεγαλύτερα πλοία, παρουσιάστηκε ένα πρόβλημα διότι η κατασκευή της γέφυρας αυτής δεν επέτρεπε σε ψηλά πλοία να διασχίζουν τον ποταμό. Επομένως αποφασίστηκε όπως γίνουν κάποιες αλλαγές στη γέφυρα, ώστε να μπορεί να κινείται όποτε χρειάζεται να περάσει κάποιο ψηλό πλοίο από κάτω. Εκτός από αυτό έκαναν τη γέφυρα πιο πλατιά ώστε να μπορούν να κυκλοφορούν ανά πάσα στιγμή περισσότερα οχήματα.



Η πόλη της Βουδαπέστης

Προσπαθήστε να εντοπίσετε στην ιστορία που διαβάσατε τη διαδικασία που ακολουθήθηκε, δηλαδή, τα στάδια που ακολουθήθηκαν σε αυτή την περίπτωση.



Παραδείγματα επιδιώξεων για γενίκευση επιδίωξης της τεχνολογίας

Προσπαθήστε να ομαδοποιήσετε τις ακόλουθες ερευνητικές προσπάθειες σε δύο ομάδες ανάλογα με το αν ανήκουν ή όχι στην ίδια ομάδα με τη δική σας έρευνα που κάνατε.

Εξηγήστε την απάντησή σας…

1. Στη γειτονιά του Μιχάλη τα τελευταία χρόνια έχουν μετακομίσει πολλοί καινούριοι κάτοικοι με αποτέλεσμα ο δρόμος να γεμίζει με σταθμευμένα αυτοκίνητα και στις δύο πλευρές. Χρειάζεται να βρεθεί κάποιος τρόπος ώστε να μην παρκάρουν τα αυτοκίνητά τους στο δρόμο γιατί γίνεται πολύ στενός και δεν χωρούν να περάσουν δύο αυτοκίνητα.
2. Σήμερα η Αλίκη έκλαιγε στο σχολείο διότι έχασε την αγαπημένη της κούκλα. Η φίλη της η Μαίρη αποφάσισε να κάνει μια έρευνα σε όλα τα καταστήματα παιγνιδιών της πόλης, ώστε να βρει μια κούκλα που να μοιάζει σε αυτήν που έχασε η Αλίκη και έτσι να τη βοηθήσει στο πρόβλημά της.
3. Τα τελευταία χρόνια στην Κύπρο δεν βρέχει πολύ, γι' αυτό χρειάζεται να βρούμε τρόπους εξοικονόμησης νερού.
4. Στη Φιλανδία οι χειμώνες είναι πολύ άσχημοι διότι έχει πολλές καταιγίδες και κεραυνούς, οι οποίοι προκαλούν πολλές καταστροφές. Οι κάτοικοι της χώρας χρειάζονται να βρουν τρόπους να προστατεύονται από τους κεραυνούς.
5. Θέλουμε να καταλάβουμε πώς δημιουργείται το χιόνι.
6. Η Σοφία θέλει να μάθει κατά πόσο θα βρέξει αύριο για να αποφασίσει αν θα πάει αύριο εκδρομή με τις φίλες της.
7. Ο Λεωνίδας είναι υπεύθυνος για την καθαριότητα του πάρκου της γειτονιάς του. Χρειάζεται ένα να τρόπο ώστε να μαζεύει τα σκουπίδια από το πάρκο χωρίς να τα παίρνει με τα χέρια του.
8. Στο εργοστάσιο υφασμάτων που δουλεύουμε προσπαθούμε να τροποποιήσουμε και να βελτιώσουμε κάποια υφάσματα ώστε να μην τσαλακώνονται.
9. Εντοπίστηκε διαρροή νερού στο φράγμα του Ξυλιάτου. Προσπαθούμε να εντοπίσουμε την εστία του προβλήματος.

22 Μαΐου 1609

Γεια σας,

Ονομάζομαι Γαλιλαίος Γαλιλέι και είμαι καθηγητής και ερευνητής στο Πανεπιστήμιο της Πάδοβας στην Ιταλία. Με ενδιαφέρει πολύ η παρατήρηση των μεγάλων άστρων, όπως είναι η Σελήνη, η Αφροδίτη, κ.ά.

Έχω μάθει από ένα οικογενειακό μου φίλο, το Δόγη της Βενετίας Ερρίκο Β’ για την επινόηση ενός σπουδαίου οπτικού οργάνου από κάποιους άλλους ερευνητές. Ονομάζεται **τηλεσκόπιο** και έχει τη δυνατότητα να μεγεθύνει μακρινά αντικείμενα. Όποιος το χρησιμοποιεί μπορεί να βλέπει τα μακρινά αντικείμενα πολύ πιο κοντά και πολύ πιο μεγάλα από ότι είναι στην πραγματικότητα. Αποτελείται από ένα σωλήνα, ο οποίος έχε στα δύο άκρα του δύο φακούς: τον **αντικειμενικό φακό** (ο φακός που βρίσκεται στη μεριά του αντικειμένου) και τον **προσοφθάλμιο φακό** (ο φακός που είναι προς τη μεριά του ματιού).

Σκέφτομαι ότι με ένα δυνατό τηλεσκόπιο θα μπορούσα να παρατηρήσω καλύτερα τα αστέρια και να προχωρήσω στις έρευνές μου. Βέβαια, το τηλεσκόπιο του φίλου μου χρησιμοποιείται για παρατήρηση πουλιών στο κυνήγι, ενώ εγώ το χρειάζομαι για να παρατηρήσω πολύ πιο μακρινά αντικείμενα. Όμως, **αν καταλάβω πώς λειτουργεί το τηλεσκόπιο, τότε ίσως αυτό να με βοηθήσει στις έρευνές μου**.

Εδώ είναι που χρειάζομαι τη βοήθειά σας. Γνωρίζω ότι κι εσείς ασχολείστε με αυτά τα θέματα γι’ αυτό θέλω να με

βοηθήσετε να καταλάβω λίγα περισσότερα πράγματα για το τηλεσκόπιο συγκεκριμένα για το πώς λειτουργούν οι φακοί…

Θα περιμένω νέα σας.

Ευχαριστώ εκ των προτέρων,

Γαλιλαίος

Ονόματα ερευνητών: ……………………………………………………………………………

1. Πού χρησιμοποιούνται οι φακοί στην καθημερινή μας ζωή;

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____

____

2. Προμηθευτείτε δύο φακούς από τη δασκάλα. Νομίζετε πώς είναι οι ίδιοι; Αν διαφέρουν, πώς διαφέρουν;

____

____

____

Το ξέρατε ότι μπορείτε να κάψετε χαρτί χρησιμοποιώντας ένα φακό;
Αν ναι, εξηγήστε στη δασκάλα σας πώς μπορείτε να το πετύχετε αυτό. Μετά από αυτό θα δοκιμάσετε να κάψετε ένα κομμάτι εφημερίδας.

Μην προχωρήσετε αν δεν μιλήσετε με τη δασκάλα σχετικά με τα πιο πάνω.

3. Εξηγήστε με όση πιο πολλή λεπτομέρεια μπορείτε τα βήματα που ακολουθήσατε για να κάψετε ένα χαρτί με ένα φακό.

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4. Ακολουθήστε τα βήματα που γράψατε πιο πάνω για να κάψετε χαρτί με ένα άλλο φακό. Καίγεται στην ίδια απόσταση το χαρτί; ______________________

____

Μην προχωρήσετε αν δεν μιλήσετε με τη δασκάλα σχετικά με τα πιο πάνω.

Άρα αν κατάλαβα σωστά…

Σε κάθε φακό αντιστοιχεί συγκεκριμένη απόσταση στην οποία όταν τοποθετήσουμε ένα κομμάτι χαρτί, τότε αυτό καίγεται. Ας ονομάσουμε αυτή την απόσταση ως **<u>εστιακή απόσταση</u>** του φακού.

Ο λόγος που καίγεται το χαρτί στη συγκεκριμένη απόσταση είναι διότι ο φακός συγκεντρώνει το φως του ήλιου πάνω στο χαρτί σχηματίζοντας μια φωτεινή κηλίδα. Αυτή η κηλίδα ονομάζεται **<u>είδωλο</u>** του ήλιου. Στην περίπτωσή μας επειδή ο ήλιος έχει πολύ δυνατό φως, το είδωλό του είναι πολύ φωτεινό, γι’ αυτό και καίγεται το χαρτί!

Γαλιλαίος

5. Χρησιμοποιήστε ένα φακό για να σχηματίσετε τα είδωλα διαφόρων φωτεινών αντικειμένων (π.χ., λάμπα της τάξης, παράθυρο, κλπ.) πάνω στον τοίχο της τάξης. Προσπαθήστε να σχηματίσετε ευκρινή (δηλαδή όχι θολά) είδωλα των αντικειμένων. Εμφανίζονται στις ίδια απόσταση από τον τοίχο τα διάφορα είδωλα;

____

____

<u>Μην προχωρήσετε αν δεν μιλήσετε με τη δασκάλα σχετικά με τα πιο πάνω.</u>

Διερωτούμαι κατά πόσο η **απόσταση αντικειμένου-φακού** *επηρεάζει* την **απόσταση φακού-ευκρινούς**

Γαλιλαίος

Η απόσταση αντικειμένου-φακού επηρεάζει την απόσταση φακού-ευκρινούς ειδώλου; Ας βοηθήσουμε το Γαλιλαίο να απαντήσει σε αυτό το ερώτημα κάνοντας μια διερεύνηση…

1. Για να διερευνήσουμε το ερώτημα του Γαλιλαίου, θα χρειαστούμε τα ακόλουθα υλικά:

- Ένα μεγεθυντικό φακό
- Μια βάση για το φακό
- Μια οθόνη πάνω στην οποία θα σχηματίζετε το είδωλο κάθε φορά
- Ρίγα για να μετράτε τις διάφορες αποστάσεις

2. Τοποθετήστε το φακό πάνω στη βάση του και βάλτε τον ανάμεσα στη λάμπα και την οθόνη

3. Χρησιμοποιήστε τη ρίγα σας για να τοποθετήσετε το φακό σε τόση απόσταση από τη λάμπα όση γράφει στην τρίτη στήλη του πίνακα στην επόμενη σελίδα.

4. Ανάψετε τη λάμπα.

5. Μετακινήστε την οθόνη μπροστά-πίσω μέχρι να σχηματιστεί ευκρινές (καθαρό, όχι θολό) είδωλο πάνω της.

6. Μετρήστε την απόσταση στην οποία σχηματίζετε ευκρινές είδωλο και καταγράψτε την στην τέταρτη στήλη του πιο κάτω πίνακα

7. Επαναλάβετε τα βήματα 3-6 για άλλες τέσσερις φορές και συμπληρώστε τον πίνακα.

<u>Προσοχή</u>: Για να είναι δίκαιο το πείραμα, χρειάζεται κάθε φορά να αλλάζετε μόνο ένα παράγοντα (απόσταση λάμπας-φακού), να μετράτε έναν άλλο παράγοντα (απόσταση φακού-ευκρινούς ειδώλου) και να κρατείτε σταθερούς όλους τους υπόλοιπους παράγοντες (ίδιος φακός, ίδια οθόνη, ίδια λάμπα).

<u>ΠΙΝΑΚΑΣ ΑΠΟΤΕΛΕΣΜΑΤΩΝ</u>

	Εστιακή απόσταση φακού (εκατοστόμετρα, cm)	<u>Παράγοντας που μεταβάλλουμε</u> Απόσταση φωτεινού αντικειμένου – φακού (εκατοστόμετρα, cm)	<u>Παράγοντας που μετρούμε</u> Απόσταση φακού-ευκρινούς ειδώλου (εκατοστόμετρα, cm)
1)		40	
2)			
3)			
4)			
5)			

<u>Στη συνέχεια εξηγήστε τι σκεφτήκατε στη δασκάλα</u>.

8. Ποιο είναι το συμπέρασμά σας; Δηλαδή ποια είναι η απάντηση στο ερώτημα του Γαλιλαίου;

____

____

9. Συγκρίνετε την απόσταση φακού-ευκρινούς ειδώλου με την εστιακή απόσταση του φακού σας, καθώς μεγαλώνει η απόσταση αντικειμένου-φακού. Τι παρατηρείτε;

____

____

Στη συνέχεια ετοιμαστείτε ώστε να παρουσιάσετε τα αποτελέσματά σας στις άλλες ομάδες ερευνητών.

Αγαπητοί μου ερευνητές, μετά από την διερεύνηση που κάνατε, εμένα μου προέκυψε και ένα άλλο ερώτημα. Άραγε **η εστιακή απόσταση *επηρεάζει* το μέγεθος του ειδώλου ενός πολύ μακρινού αντικειμένου;** Προσπάθησα να ακολουθήσω την ίδια διαδικασία που ακολουθήσατε κι εσείς προηγουμένως.

Δηλαδή έκανα τα εξής:

1. Πήρα ένα μεγεθυντικό φακό και εντόπισα την εστιακή του απόσταση, μετρώντας την απόσταση στην οποία καίγεται ένα κομμάτι χαρτί όταν το βάλω κάτω από τον ήλιο και από πάνω του έχω τον φακό.
2. Χρησιμοποίησα το φακό για να σχηματίσω το είδωλο ενός μακρινού αντικειμένου πάνω σε μια οθόνη.
3. Μέτρησα και κατέγραψα σε πίνακα τα ακόλουθα: απόσταση αντικειμένου-φακού, απόσταση φακού-ευκρινούς ειδώλου, μέγεθος αντικειμένου, μέγεθος ειδώλου.
4. Επανέλαβα το πείραμα ακόμη 4 φορές χρησιμοποιώντας κάθε φορά διαφορετικό φακό. Εντόπιζα την απόσταση στην οποία σχηματιζόταν ευκρινές είδωλο και μετρούσα το μέγεθός του. Σε κάθε πείραμα χρησιμοποίησα το ίδιο αντικείμενο, στην ίδια απόσταση από το φακό.
5. Οι μετρήσεις μου φαίνονται στον πιο κάτω πίνακα.

Μέγεθος αντικειμένου	**Απόσταση αντικειμένου-φακού**	**Εστιακή απόσταση φακού**	**Απόσταση φακού-ειδώλου**	**Μέγεθος ειδώλου**
80 cm	2500 cm	10 cm	10 cm	2 cm
80 cm	2500 cm	15 cm	15 cm	3 cm
80 cm	2500 cm	20 cm	20 cm	4 cm
80 cm	2500 cm	25 cm	25 cm	5 cm
80 cm	2500 cm	30 cm	30 cm	6 cm

1. Ποιο είναι το ερώτημα που απασχολεί το Γαλιλαίο;

Η ____ επηρεάζει την ____ ;

2. Ποιο παράγοντα έχει μεταβάλει; Πώς το έκανε;

4. Ποιο παράγοντα έχει μετρήσει; Πώς το έκανε;

5. Ποιους παράγοντες κράτησε σταθερούς;

6. Σε ποιο συμπέρασμα μας οδηγούν τα αποτελέσματα του Γαλιλαίου; Δηλαδή ποια είναι η απάντηση στο δεύτερο ερώτημα που τον απασχόλησε;

Στη συνέχεια ετοιμαστείτε ώστε να παρουσιάσετε τα αποτελέσματά σας στις άλλες ομάδες ερευνητών.

*Παραδείγματα επιδιώξεων για γενίκευση επιδίωξης της επιστήμης_*

Προσπαθήστε να δείτε κατά πόσο η ακόλουθη έρευνα ανήκει στην ίδια ομάδα ή όχι με τη δική σας έρευνα που κάνατε για να μάθετε πώς λειτουργούν οι φακοί. Εξηγήστε την απάντησή σας…

- Θέλουμε να καταλάβουμε πώς δημιουργήθηκε η τρύπα του όζοντος
- Θα προσπαθήσουμε να καταλάβουμε κατά πόσο η χρήση κινητού τηλεφώνου επηρεάζει την ακοή.
- Θα ψάξουμε στη γραμματική για να βρούμε τις εξαιρέσεις του κανόνα για τα ρήματα σε -ίζω
- Ο πονοκέφαλος είναι μια πολύ συνηθισμένη πάθηση η οποία μπορεί να οφείλεται σε πολλούς λόγους. Προσπαθούμε να εξηγήσουμε πώς δημιουργείται ο πονοκέφαλος.
- Θα κάνουμε μια έρευνα για να δούμε πόσο νερό καταναλώνεται στα νοικοκυριά του χωριού μας.
- Εμείς παρατηρούμε τη ζωή των πάπιων στη λίμνη του πάρκου της Αθαλάσσας ώστε να καταλάβουμε με ποιο τρόπο μεγαλώνουν τα παιδιά τους.

Θα προσπαθήσουμε να καταλάβουμε κατά πόσο η χρήση κινητού τηλεφώνου επηρεάζει την ακοή.

Μαθητής 1: Η έρευνα αυτή αποκλείεται να ανήκει στον κλάδο της επιστήμης, διότι η έρευνά τους σχετίζεται με κινητά τηλέφωνα, που είναι κάτι τεχνολογικό.

Μαθητής 2: Διαφωνώ μαζί σου. Αυτό που προσπαθούν να κάνουν είναι να μάθουν κάτι που δε ξέρουν σχετικά με τη λειτουργία των κινητών τηλεφώνων. Κάτι τέτοιο το κάνουν οι επιστήμονες και όχι οι τεχνολόγοι.

Συμφωνείτε ή διαφωνείτε με κάποιο από τους δύο μαθητές;

Προσπαθήστε να ομαδοποιήσετε τις ακόλουθες περιπτώσεις σε δύο ομάδες ανάλογα με τον στόχο τους, δηλαδή με το τι προσπαθούν να κάνουν

1. Δεν γνωρίζουμε τις εξαιρέσεις του κανόνα για τα ρήματα σε –ίζω. Γι' αυτό θα ψάξουμε στη γραμματική για να τις βρούμε.
2. Θα ψάξουμε σε διάφορες εγκυκλοπαίδειες για να δούμε τι λένε σχετικά με τους λόγους που δημιουργήθηκε η τρύπα του όζοντος.
3. Πριν από 10 χρόνια μια ομάδα ερευνητών άρχισαν να ερευνούν για το πώς δημιουργήθηκε η τρύπα του όζοντος. Ήταν οι πρώτοι που τους απασχόλησε αυτό το ερώτημα.
4. Θα ψάξουμε στο διαδίκτυο για να βρούμε πληροφορίες για το πώς κατασκευάστηκε ο πρώτος ηλεκτρονικός υπολογιστής
5. Εξετάζουμε κατά πόσο οι οθόνες των ηλεκτρονικών υπολογιστών είναι επικίνδυνες για τα μάτια μας και τι είδους προβλήματα μπορεί να προκαλούν.
6. Έχουμε αγοράσει ένα νέο είδος ηλεκτρονικού υπολογιστή. Θα διαβάσουμε τις οδηγίες χρήσεως για να μάθουμε πώς να τον χρησιμοποιήσουμε.

Προσπαθήστε να ομαδοποιήσετε τις ακόλουθες περιπτώσεις σε δύο ομάδες ανάλογα με τον στόχο τους, δηλαδή με το τι προσπαθούν να κάνουν

1. Προσπαθούμε να βρούμε τρόπους ώστε να κάνουμε τις οθόνες των ηλεκτρονικών υπολογιστών λιγότερο βλαβερές.
2. Χρησιμοποιήσουμε ηλεκτρονικό υπολογιστή για να ετοιμάσουμε την εργασία μας για ένα ευρωπαϊκό διαγωνισμό.
3. Θέλουμε να φτιάξουμε πιο γρήγορους ηλεκτρονικούς υπολογιστές.
4. Εντοπίστηκε διαρροή νερού στο φράγμα του Κούρρη. Προσπαθούμε να εντοπίσουμε την εστία του προβλήματος.
5. Τα τελευταία χρόνια στην Κύπρο δεν βρέχει πολύ, γι' αυτό χρειάζεται να βρούμε τρόπους εξοικονόμησης νερού.
6. Προσπαθούμε να βρούμε λύσεις για να αντιμετωπίσουμε το πρόβλημα της αύξησης της θερμοκρασίας του πλανήτη.

Δύο ομάδες ερευνητών ασχολούνται με ένα συγκεκριμένο πρόβλημα, που αφορά στη θεραπεία μιας σπάνιας ασθένειας.

1. Η πρώτη ομάδα ερευνητών προσπαθεί να καταλάβει ποια μικρόβια οδηγούν στην εμφάνιση της ασθένειας.

2. Η δεύτερη ομάδα ερευνητών προσπαθεί να φτιάξει ένα φάρμακο που να σκοτώνει ορισμένα μικρόβια τα οποία ήδη γνωρίζουμε πώς σχετίζονται με την εμφάνιση αυτής της ασθένειας.

3. Η τρίτη ομάδα ερευνητών προσπαθεί να βρει ένα τρόπο ανίχνευσης των μικροβίων της ασθένειας, π.χ., μέσω κάποιας ειδικής ανάλυσης αίματος.

Τι είδους έρευνα κάνει η κάθε ομάδα; Επιστημονική ή τεχνολογική; Εξηγήστε την απάντησή σας.

Πιστεύετε ότι υπάρχουν περιπτώσεις όπου η έρευνα που κάνει κάποια από τις τρεις ομάδες ερευνητών είναι χρήσιμη για κάποιαν από τις υπόλοιπες; Σκεφτείτε όλες τις περιπτώσεις και εξηγήστε την απάντησή σας.

Παίρνουμε δύο ίδια δοχεία, τα γεμίζουμε με την ίδια ποσότητα νερού και τα βάζουμε μέσα στο ίδιο δωμάτιο. Στο ένα δοχείο έχει μέσα κρύο νερό από το ψυγείο και στο άλλο δοχείο έχει μέσα ζεστό νερό. Τοποθετούμε μέσα σε κάθε δοχείο από ένα παγάκι και χρονομετρούμε πόσο χρειάζεται μέχρι να λιώσει το παγάκι. Αν τα δύο παγάκια λιώσουν σε διαφορετικό χρόνο, τότε αυτό σημαίνει ότι η θερμοκρασία του νερού επηρεάζει το χρόνο που χρειάζεται για να λιώσει ένα παγάκι.

Η πιο πάνω περιγραφή ταιριάζει με κάποια στάδια κάποιου από τα δύο διαγράμματα που έχετε μπροστά σας;

Σε ένα ερευνητικό εργαστήριο οι ερευνητές κάνουν διάφορα πειράματα με τα διάφορα υφάσματα, ώστε να βρουν ένα τρόπο τα ρούχα να μη τσαλακώνονται. Πειραματίζονται με διάφορα υλικά μέχρι να εντοπίσουν την κατάλληλη ουσία χρειάζονται. Μόλις τη βρουν θα τη δοκιμάσουν πάνω σε διάφορα υφάσματα για να δουν σε ποιο βαθμό καταφέρνει να κάνει τα διάφορα υφάσματα να μη τσαλακώνονται.

Η πιο πάνω περιγραφή ταιριάζει με κάποια στάδια κάποιου από τα δύο διαγράμματα που έχετε μπροστά σας;

Διαβάστε τα ακόλουθα αποσπάσματα από το ημερολόγιο του Γαλιλαίου. Κάθε απόσπασμα περιγράφει και ένα είδος έρευνας.
Συζητήστε στην ομάδα σας τις ερωτήσεις που υπάρχουν σχετικά με το ημερολόγιο αυτό.

19 Μαΐου 1609

Αγαπητό μου ημερολόγιο,

Σήμερα πήρα ένα γράμμα από ένα φίλο μου από τη Βενετία, το Δόγη Ερρίκο. Μου λέει για ένα νέο οπτικό όργανο που εφευρέθηκε. Ονομάζεται τηλεσκόπιο και έχει τη δυνατότητα να κάνει τα μακρινά αντικείμενα να φαίνονται πιο μεγάλα και πιο κοντινά. Υπεύθυνοι για αυτή την επινόηση είναι κάποιοι ερευνητές οι οποίοι είχαν αρχικά λάβει επιστολή στην οποία ο φίλος μου τους ζητούσε βοήθεια γιατί χρειαζόταν ένα τρόπο ώστε να μπορεί να εντοπίζει εύκολα το θήραμά του στο κυνήγι πουλιών. Οι ερευνητές αυτοί έψαξαν ανάμεσα σε διάφορες πιθανές λύσεις για να βρουν το οπτικό όργανο που θα ταίριαζε καλύτερα στις ανάγκες του φίλου μου. Αφού βρήκαν ότι το τηλεσκόπιο θα μπορούσε να τον βοηθήσει, έφτιαξαν ένα γι' αυτόν και το δοκίμασαν για να δουν σε ποιο βαθμό λειτουργεί.

Γαλιλαίος

Η έρευνα που περιγράφεται δίπλα ανήκει στην επιστήμη, στην τεχνολογία ή σε κανένα από τα δύο είδη ερευνών; Πώς σκεφτήκατε για να αποφασίσατε; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ____________________________________

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25 Μαΐου 1609

Αγαπητό μου ημερολόγιο,

Από τη μέρα που έμαθα για την ανακάλυψη του τηλεσκοπίου, έχω την περιέργεια να μάθω πώς λειτουργεί το τηλεσκόπιο και έχει την ικανότητα να μεγαλώνει τα μακρινά αντικείμενα.

Άραγε, πώς λειτουργούν οι φακοί που το αποτελούν; Παίζει ρόλο αν χρησιμοποιήσω φακούς που έχουν διαφορετική εστιακή απόσταση;

Αύριο πρωί πρωί θα κάνω κάποιες διερευνήσεις με διάφορους φακούς για να προσπαθήσω να εξηγήσω το πώς λειτουργεί το τηλεσκόπιο…

Γαλιλαίος

Η έρευνα που περιγράφεται δίπλα ανήκει:

στην επιστήμη, στην τεχνολογία ή σε κανένα από τα δύο είδη ερευνών; Πώς σκεφτήκατε για να αποφασίσατε; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ___________________________________

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Μπορείτε να εντοπίσετε στο ημερολόγιο κάποιο τρόπο με τον οποίο η ανάπτυξη της τεχνολογίας έχει βοηθήσει την ανάπτυξη της επιστήμης; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ___________________________________

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26 Μαΐου 1609

Αγαπητό μου ημερολόγιο,

Σήμερα έκανα δύο διερευνήσεις.

Στην πρώτη διερεύνηση διερεύνησα κατά πόσο η εστιακή απόσταση του αντικειμενικού φακού του τηλεσκοπίου επηρεάζει τη μεγέθυνσή του, δηλαδή το πόσες φορές μεγαλώνει τα μακρινά αντικείμενα. Βασικά έφτιαξα διάφορα τηλεσκόπια, τα οποία όμως είχαν διαφορετικό αντικειμενικό φακό. Τα χρησιμοποίησα για να παρατηρώ τη σελήνη και κάθε φορά υπολόγιζα τη μεγέθυνσή της. Το συμπέρασμά μου ήταν ότι όσο πιο μεγάλη η εστιακή απόσταση του αντικειμενικού φακού, τόσο πιο μεγάλα φαίνονται τα αντικείμενα.

Με παρόμοιο τρόπο έκανα και μια δεύτερη διερεύνηση για να μάθω κατά πόσο η εστιακή απόσταση του προσοφθάλμιου φακού επηρεάζει τη μεγέθυνση του τηλεσκοπίου. Τα αποτελέσματα αυτής της διερεύνησης με οδήγησαν στο συμπέρασμα ότι όσο πιο μικρή η εστιακή απόσταση του προσοφθάλμιου, τόσο πιο μεγάλα φαίνονται τα αντικείμενα.

Γαλιλαίος

Η έρευνα που περιγράφεται δίπλα ανήκει στην επιστήμη, στην τεχνολογία ή σε κανένα από τα δύο είδη ερευνών; Πώς σκεφτήκατε για να αποφασίσατε; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ________________________________

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27 Μαΐου 1609

Αγαπητό μου ημερολόγιο,

Τα συμπεράσματα που έβγαλα από τις δύο διερευνήσεις που έκανα χτες, με βοήθησαν να αποφασίσω τι φακούς πρέπει να χρησιμοποιήσω για να φτιάξω ένα τηλεσκόπιο το οποίο να μεγεθύνει πολύ περισσότερο από ότι μεγεθύνει το τηλεσκόπιο του Δόγη Ερρίκου.

Συγκεκριμένα, έφτιαξα δύο φακούς. Ο πρώτος έχει πολύ μεγάλη εστιακή απόσταση, ενώ ο δεύτερος πολύ μικρή. Βρήκα την απόσταση στην οποία πρέπει να τοποθετηθούν και στη συνέχεια τοποθέτησα τους δύο φακούς σε ένα σωλήνα κατάλληλου μήκους. Το αποτέλεσμα ήταν εκπληκτικό! Αν έκανα σωστά τους υπολογισμούς μου, το τηλεσκόπιό μου έχει μεγέθυνση 20, δηλαδή κάνει μακρινά αντικείμενα να φαίνονται 20 φορές μεγαλύτερα.

Γαλιλαίος

Η έρευνα που περιγράφεται δίπλα ανήκει στην επιστήμη, στην τεχνολογία ή σε κανένα από τα δύο είδη ερευνών; Πώς σκεφτήκατε για να αποφασίσατε; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ____________________________________

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Έχει βοηθήσει η επιστήμη την τεχνολογία με οποιοδήποτε τρόπο σε αυτή την περίπτωση; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ____________________________________

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31 Μαΐου 1609

Αγαπητό μου ημερολόγιο,

Τις τελευταίες νύχτες χρησιμοποίησα το τηλεσκόπιό μου για να παρατηρήσω διάφορα αστέρια. Προς μεγάλη μου έκπληξη παρατήρησα διάφορα πράγματα για πρώτη φορά τα οποία δεν φαίνονται με γυμνό μάτι. Παρατήρησα ότι η επιφάνεια της Σελήνης δεν είναι λεία αλλά αποτελείται από βουνά, κοιλάδες και πολλούς κρατήρες. Επίσης είδα ότι ο πλανήτης Αφροδίτη αλλάζει σχήμα κάθε βράδυ όπως και η Σελήνη. Ακόμη είδα ότι ο πλανήτης Δίας έχει κι εκείνος όπως και η γη, όχι ένα αλλά τέσσερα δικά του φεγγάρια! Θα συνεχίσω τις παρατηρήσεις μου γιατί θέλω να μελετήσω και να μάθω περισσότερα πράγματα για την κίνηση των διαφόρων πλανητών.

Γαλιλαίος

Η έρευνα που περιγράφεται δίπλα ανήκει στην επιστήμη, στην τεχνολογία ή σε κανένα από τα δύο είδη ερευνών; Πώς σκεφτήκατε για να αποφασίσατε; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ____________________________________

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Έχει βοηθήσει η τεχνολογία την επιστήμη με οποιοδήποτε τρόπο σε αυτή την περίπτωση; Συζητήστε το στην ομάδα σας.

Σημειώσεις: ____________________________________

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Appendix F: Teaching-Learning materials used in Study 3

Published in:

Constantinou C.P, Livitzis M., Hadjilouca R., Scholinaki A., Papaevripidou M., Papadouris N., et al. (2010b). *Electromagnetic properties of materials: Teaching and learning activities. (in Greek and English)*. Learning in Science Group, University of Cyprus, ISBN: 978-9963 689-58-3 978-9963-689-56-9.