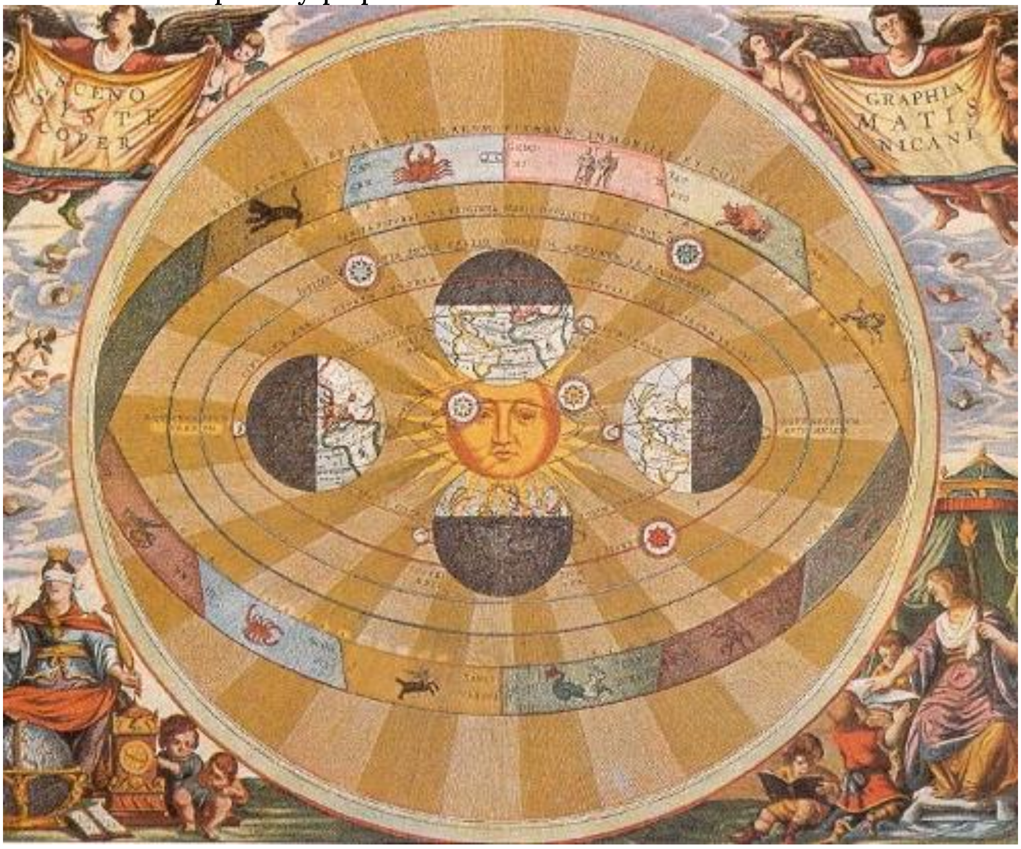
From the geocentric to the heliocentric system: An educational scenario based on the history of science in which students produce animation movies

Keywords: geocentric - heliocentric debate, nature of science, animation movies developed by pupils



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Implementation of the case study in the science classroom: Sylvi Ioakeimidou, teacher

3. Abstract

The design of the instructional material of this educational scenario entitled "From the geocentric to the heliocentric system" is based on the study of the history of astronomy and especially on the competing explanations on the solar system models (e.g. Aristotle's, Aristarchus's, Ptolemy's, Copernicus's, Brahe's models, Galileo's, Kepler's work) and crucial cases that highlight science as developmental and changeable and also portray it as rooted in culture, history and society as a whole. In the implementation of the designed instructional material, adopting the assumption for the learning of science as developmental process of appropriation-transformation through participation in gradually evolving discourses and practices, we try to create both a collaborative inquiry in nature learning environment aiming to promote students' learning about

aspects of the nature of science. The educational scenario is appropriate for students of the upper elementary school. According to the teaching sequence students study important science event concerning the geocentric - heliocentric debate and the assumption these science events are based and discuss about aspects of the nature of science and science processes such as observation, hypothesis, and the use of evidence, the creation of models, and the modification of these models. The learning activities of the educational scenario are based on variety of teaching strategies (e.g. movies, animations, discussions) but the basic strategy is that students produce their own animation movies concerning the geocentric - heliocentric debate. During this procedure students chose the narrative technique and the way that they will present their thoughts on the geocentric - heliocentric debate in a movie and prepare the relative texts (monologues and/or dialogues). Finally, using appropriate prototypes write the synopsis of the movie, create the story board, the flip book and finally create their movies.

4. Description of case study

Educational scenario's approach is collaborative inquiry which stems from sociocultural orientations (e.g. Wells & Claxton 2002). According to sociocultural theories learning process can be regarded as a transformative process of participation in appropriate discourses and practises. In this context, learning is a meaning-making collaborative inquiry process that occurs through participation in appropriate designed activities with peers and other more knowledgeable members (e.g. teacher) of the culture. The design of the teaching scenario has focused on the participation of pupils in gradually evolving discourses and practices concerning geocentric-heliocentric debate encouraging an appreciation of aspects of the nature of science. During the developed teaching sequence pupils study selected science events concerning the geocentric - heliocentric debate and discuss about the nature of science (e.g. the role of observation and hypothesis, the use of evidence, the creation and modification of models). Thereafter pupils produce their own movies using the results and the material they have gathered form their research in the geocentric-heliocentric debate historical material.

The Educational Value of Animation Movies' Creation by the Students

The animation is an expressive mean with exceptional expressive and representative features. The expressive possibilities of this technique have highlighted it as one of the key tools for creating educational multimedia (Boyle, 1997). The term animation is defined as any sequence created picture by picture or otherwise, in film terminology, frame by frame. Animation is a series of still images. The creation of each picture-frame can be done with various ways and materials (Halas & Manvell 1969; Laybourne 1998). It could be of drawings, objects, or people in various positions. However, when played back, it produces a stream of unbroken motion. Consisting of a series of drawings or photographs on paper, animation can be viewed with a mechanical device or flipping through hand-held sequence of images. The use of the expressive means of the animation technique in the educational scenario and especially the involvement of the pupils in order to produce their own animation movies may assist in achieving objectives that can concern content, processes and skills. The usefulness of the procedure of animation movies' creation by pupils during educational process could be traced to two key characteristics of this technique:

a. The constructive distinctiveness of animation technique: Multiple means of engagement

The construction of an animation movie in the context of a teaching scenario can be achieved with excellent results through the use of simple everyday materials such as plasticine, paper, cloths, photos and others that may be available at each school. The majority of schools have the necessary digital equipment for the creation of simple movie animations. So the animation can be considered as a technique that enables experimentation and exploration in the audiovisual language with a minimal cost at any place and any means available to an amateur who wants to use that language. Furthermore, animation movies give space to pupils' creativity. Pupils can choose to animate objects, cut out figures, their own drawings, their own body etc. They can choose to use text, images, dramatic practices or a combination of them. They can choose to add sound. The can choose to add audio descriptions using their own voices. Multiple opportunities for choice are embedded into the animation movie making experience. Finally, by providing a tool for expression that is so engaging and flexible, teachers gain a more accurate window into their students' understandings.

b. The collaborative inquiry nature of the process of creating an animation: Synthesizing multiple means of action and expression

In the animation movie making experience, pupils have the opportunity to compare different solutions on the movie making problems they face, where various expressive aspects and means are combined to be produced a single result. Animation movies' creation by the pupils in teams is a unique and engaging way for pupils to express their ideas, apply their abilities and finally coordinate and synthesize them. Each pupil involved can through the collective process of creating the animation movie gradually become familiar and develop new skills, while at the same time understand better and appropriate elements (concepts, procedures, skills etc.) related to the topic of the produced film. In our occasion having pupils as a basic task of creating an animated film on the evolution of scientific views about the astronomical models through the history of the science, they should cooperate and interact to analyze and process relative information, to choose narrative technique to synthesize the material they collect and/or created, to become familiar with the use of the audiovisual language and ultimately to produce their film.

The proposed teaching sequence of educational scenario is the following:

<u>1st phase:</u> Orientation to the topic and the way of study (duration: 1 hour) <u>2st phase:</u> Research on aspects concerning history of astronomy (duration: 4 hours) <u>3rd phase:</u> Discussion - Selection of narrative technique of the pupils' animation movies (duration: 1 hour) <u>4th phase:</u> Synthesis and production of the animation movies material (duration: 4 hours) <u>5th phase:</u> Discussion on the proposed pupils' animations (duration: 1 hour) <u>6th phase:</u> Animation movies creation -Filming (duration: 3 hours) <u>7th phase:</u> Movies presentation and

evaluation (duration: 1 hour)

5. Historical and philosophical background

As educational material for the educational scenario we chose important episodes from the history of astronomy (e.g. Aristotle's geocentric system, Aristarchus's heliocentric system, Ptolemy's geocentric system, Copernicus's heliocentric system, Brahe's synthetic model, Galileo's telescopic discoveries, the shift from the circular to the elliptical trajectory by Kepler) in order pupils, by studying the material and trying to produce their own animation movies, to appreciate that explanations are based on models which may involve, to understand how observation, hypothesis and model are used in science to rule out alternative explanations, with the aim of reaching a single, agreed explanation, and generally to understand the evolutionary character of scientific knowledge as well as the cultural interrelations of science and society. The choice of the geocentric-heliocentric debate as the topic of the teaching scenario has to do with scientific and educational reasons.

The astronomical models that prevailed in the different faces of the history of science, as well the cultural, social and ideological dimensions that contributed in the configuration of every system are important resources of knowledge for the ways that human thought was evolved about the universe. The history of shift from the earth-centered cosmos to the sun-centered model is an important one to introduce pupils in science, in aspects of nature of science, in its philosophical, historical and cultural dimensions. From the standpoint of science, the passage of human thought from the geocentric to the heliocentric system clearly reflects the human effort to understand the world around him/her and it's a history very interesting for the pupils. The birth of modern science is closely connected with astronomy. Ancient astronomers showed remarkable skill in devising theories and applying mathematical devices to account for these motions. The story of how humans came to create and then abandon the Ptolemaic system is among the most interesting and dramatic narratives in all of history (Crowe 2001). The ideas of Aristotle, and Ptolemy's model of the universe, were widely accepted and became very influential. However, astronomers were becoming increasingly aware that Ptolemy's model did not lead to completely accurate predictions. Copernicus wrote a book which started a revolution about the universe. The Copernican revolution was a revolution in ideas, a transformation in man's conception of the universe and of his own relation to it (Kuhn, 1985).

According to A. Koyre:

"The development of the new cosmology, which replaced the geo or even anthropocentric world of Greek and mediaeval astronomy by the heliocentric, and later, by the centerless universe of modern astronomy, played a paramount role in this process …o deep revolution which changed the very framework and patterns of our thinking…" (Koyre, 1957, p. 6)

Kuhn supports that:

"the story of the Copernican Revolution… its core was a transformation of mathematical astronomy, but it embraced conceptual changes in cosmology, physics, philosophy, and religious as well" (Kuhn,1985, p. vii)

As the development of individual children's thinking on the solar system in many aspects keeps pace with the historical development of scientific ideas about this (see section 8: obstacles to teaching and learning), their study for a HPS perspective, in an appropriately designed educational scenario, may offer important learning opportunities to be discussed issues concerning scientific concepts, scientific processes and other aspect of the NOS.

Aristotle's theory of the solar system (*Encyclopædia Britannica, Inc.*)

Ptolemy: theory of the solar system (*Encyclopædia Britannica, Inc.*)

6. Target group, curricular relevance and didactical benefit

The instructional material of the educational scenario is appropriate for students of the upper elementary school (11-12 years old). The educational scenario can be also used in pre-service or in-service teachers' training as an example of a way to incorporate issues concerning history of science in learning science to teach both science concepts and important aspects of nature of science.

Through their involvement with the activities of the teaching scenario pupils are expected to study milestones and important facts of the geocentric-heliocentric debate and the assumptions in which were based the proposed cosmological models, to reflect on their succession through the study of appropriate chosen historical events and discuss (using gradually the appropriate scientific terminology: planet, star, retrograde motion, trajectory, rotation) about important aspects of the nature of science, such as:

- How science knowledge is developed? To discuss and become familiar with scientific possess, such as observation, hypothesis and model.
- What procedures and practices are followed by the scientists? For example, pupils to «follow up» the shift from naked-eye observation to observation through instruments, from the simple observation to the record of observations and in their study and their interpretation.
- How do social and cultural contexts affect the way scientists work? For example, two reasons that the proposed Aristarchus's heliocentric system was not established in, as it has been argued, is that the acknowledgment of the motion of the earth was in contrast with the religious beliefs of the time, and also in contrast with the prevailing -based in experience- intuitive idea that the Earth is stationary.

At the same time objectives are also pupils to be familiarized with the film language of animation and in particular:

- To improve their communication skills and be acquainted with the use of audiovisual and digital technology.

- To be familiar with qualitative characteristics of the audiovisual language in order to can act as critical «readers».
- To be able to understand the intrinsic elements of the audiovisual language, such the rhythm of the successive pictures to produces a stream of unbroken motion, montage, synchronisation, music, sound, etc. and can creatively use them for their learning needs.

7. Activites, methods and media for learning

A variety of narratives support the developed teaching activities of our educational scenario such as movies, animations, discussions. However, as pupils' basic mission and central teaching strategy is used the animation movie' creation by the pupils. They are asked to produce their own narratives: animation movies concerning the geocentric - heliocentric debate inspired by the history of science. Pupils work on specific worksheets under the guidance of the teacher. The activities of the educational scenario evolve as follows:

1st phase: Orientation to the topic and the way of study (duration: 1 hour)

A1. Pupils' views elicitation on the succession of the cosmological models. A2. Watching a movie relative with the history of the cosmological views aiming to provoke pupils' interest; A3. Demonstration of exemplary animation movies that they have been created form other pupils in the context of other projects so as to be achieved the aim of pupils' gradual familiarisation with the technique of animation.

2nd phase: Research on aspects concerning history of astronomy (duration: 4 hours)

In this phase pupils, having in their disposal appropriate work sheets, research the role of scientists concerning geocentric or heliocentric models from ancient years until the era that Copernicus, Galileo and Kepler lived.

B1. Following the "time line" technique pupils fill a semi-filed table, write the event that concerns every scientist and with the guidance of the teacher agree in one or more scientific process that fit to every scientist and the relative event, such as on the following example.

Time	***Scientist***	***event***	***Scientific process***
285 B.C.	Aristarchus	Proposed a new model (a heliocentric model)	A new hypothesis leads in the creation of a new model

B2 After their research pupils discuss in teams and in the whole classrooms questions, such as following:

- Are always our emotions, such as vision, a reliable way to study the physical world? We support with arguments our opinions.
- What are the reasons that lead in the defeat of the Aristarchus' views of a sun-

centered model? -
How has changed the way of observing things during the centuries? How does the use of telescope by Galileo affect the geocentric-heliocentric debate?

3rd phase: Discussion - Selection of narrative technique of the pupils' animation movies (duration: 1 hour)
Pupils choose the narrative technique they were following to organize and synthesize the material they studied.

4th phase: Synthesis and production of the animation movies material (duration: 4 hours)
In this phase pupils decide about the way of which they will present their thoughts on the geocentric - heliocentric debate in an animation movie and prepare the relative texts (monologues and/or dialogues). Using appropriate prototypes every team write the synopsis of its movie; create the story board and the flip book.

5th phase: Discussion on the proposed pupils' animations movies (duration: 1 hour)
Every team explains the way in which they will work to write the synopsis of every movie and to create the story board and the flip book.

6th phase: Animation movies creation -Filming (duration: 3 hours)
Pupils working in teams:

- Create the scenes of the movies and their elements using a variety of material (e.g. plasticine, cloths, papers, drawings). We can see in picture 1 a representation of the Tygco Brahe's model that a team of pupils created (during the implementation of the educational scenario) to use it in his production of its movie.
- Dramatize and record the texts of their movies using digital means.
- Create their final animations movies.

7th phase: Movies presentation and evaluation (duration: 1 hour)
In the final phase, every team present its movie. During this procedure pupils asses the movies and discuss on scientific concepts concerning the teaching scenario and aspects of nature of science.

8. Obstacles to teaching and learning

Pupils' alternative conceptions on astronomical models

From the perspective of children, the view of celestial bodies from the earth often creates alternative conceptions for the "picture" of our planetary system and universe in general. The fact that every day we see the sun rises in the morning, follow a cyclical pattern during the day and eventually sets in the afternoon, leads many children to "construct" a geocentric or a hybrid model (Xalkia 2006, p. 35). Liu's (2005) research, that was conducted with sixty-four third to sixth graders (8-13 years old) in Taiwan and in Germany, revealed six alternative models of the universe held by young students in Taiwan and in Germany. These models are depicted in the figure 1. As the development of individual children's thinking on the solar system in many aspects keeps pace with the historical development of scientific ideas about this, their study for a HPS perspective offers important learning opportunities to be discussed such as: - scientific concepts (e.g. planet, star, model) - scientific processes (e.g. observation, hypothesis) and - other aspect of the NOS (e.g. "scientific ideas are affected by their social and historical milieu" - McComas, 1998, "science is dynamic, changing and tentative" - Bell et al. 2000)

9. Pedagogical skills

Researchers and educators search for the best ways to use history and philosophy of science in science education. Some of these are:

- the "story-line" approach (e.g. Stinner et al 2003; Hadzigeorgiou 2006)
- case Studies (e.g. Irwin 2000; Stinner et al. 2003; Bevilaqua & Giannetto 1998),
- historically instruments -replicas (e.g. Heering et al. 1994; Riess 1995),
- dramatization - role play (e.g. Stinner et al. 2003),
- portraits of historical characters & historical vignettes,
- introduction of social and ethical contexts of science through case studies (e.g. Hagen et al. 1996),
- experimental simulations (e.g. Masson & Vázquez-Abad 2006)
- historical confrontations/debates,
- historical thought experiments (Klassen 2006; Galili 2009), and
- a variety of teaching tools such as, poster design and poster presentation, discussion on texts, web-site design.

In the same line with the above directions, in our research, we implemented and assessed the use of a new teaching tool that is the creation of animation movies by pupils which are inspired by the history of science. In these movies pupils are asked to present, narrate, dramatize, compare and remark with their own ways using a variety of expressional means the succession of the explanatory contexts that have been developed during the history of science concerning the geocentric-heliocentric debate.

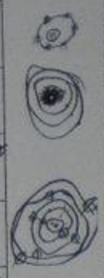
In the following presentation we can see an overall scheme of the teaching scenario, especially concerning the data sources we derive for the implementation of it, and also examples of pupils' work during project.

Reppresentative examples of pupils work during the implementation of the project in a science classroom:

Tycho Brahe's model

Πίνακας 1: Γραμμή του χρόνου: Από το γεωκεντρικό *στο* ηλιοκεντρικό *σύστημα.*

Χρονολογία	Όνομα - Επιστήμονας	Γεγονός	Επιστημονική διαδικασία
700 π.Χ.	Γη επίπεδη **Αρχαίοι Έλληνες** (Θαλής, Αναξίμανδρος...)	Παρατηρούσαν και έψαχναν τις αιτίες για το καθετί που τους ενδιέφερε και ονόμασαν κάποια άστρα που κινούνταν πλανήτες	Παρατήρηση
500 π.Χ.	**Πυθαγόρας**	Η γη βρίσκεται στο κέντρο του σύμπαντος και έχει σχήμα σφαιρικό. Περιβάλλεται από κρυστάλλινες σφαίρες και για πρώτη φορά είναι καλλιεργ[illegible]	Υπόθεση
410 π.Χ.	**Φιλόλαος**	Το σύστημα δεν είναι ούτε γεωκεντρικό ούτε ηλιοκεντρικό αλλά στο κέντρο τοποθετούσε το κεντρικό πυρ.	Υπόθεση
390 π.Χ.	**Πλάτωνας**	Πρότεινε οι αστρονόμοι να χρησιμοποιούν τα μαθηματικά και τη γεωμετρία	Πρόταση χρήσης μαθηματικών και γεωμετρίας
370 π.Χ.	**Εύδοξος**	Προσπάθησε να λύσει το πρόβλημα της ανάδρομης κίνησης των πλανητών χρησιμοποιώντας 27 ομόκεντρες σφαίρες	πρόταση μοντέλου
350 π.Χ.	**Αριστοτέλης**	Εξέλιξε το μοντέλο του Εύδοξου και πρότεινε 55 ομόκεντρες σφαίρες.	Χρησιμοποιεί ένα μοντέλο και κάνει τη δική του πρόταση
285 π.Χ.	**Αρίσταρχος**	Διατύπωση για πρώτη φορά ενός ηλιοκεντρικού μοντέλου.	Μια νέα υπόθεση οδηγεί στη διατύπωση ενός νέου μοντέλου
230 π.Χ.	**Απολλώνιος**	Πρώτη φορά διατυπώνεται ο όρος των επικύκλων δηλαδή οι πλανήτες κάνουν και μια δεύτερη κίνηση πέρα από την [illegible]	Παρατήρηση και πρόταση για βελτίωση του μοντέλου του [illegible] κίνηση που κάνει γύρω [illegible]
100 μ.Χ.	κάνει **Πτολεμαίος**	Χρήση μοντέλου των επικύκλων και το βελτιώνει καθορίζοντας λεπτομερώς τις κινήσεις των πλανητών	Το μοντέλο που υπήρχε δεν ήταν σύμφωνο με κάποιες παρατηρήσεις και προτείνονται αλλαγές σε αυτό.
1510 μ.Χ.	**Κοπέρνικος**	ο ήλιος είναι στο κέντρο, η γη γυρίζει γύρω από τον εαυτό της και γύρω από τον ήλιο	Παρατήρηση νέου μοντέλου
1560 μ.Χ.	**Τύχο Μπράχε**	Η γη είναι στο κέντρο του κόσμου αλλά όλοι οι πλανήτες γυρνάνε γύρω από τον ήλιο	Η επιστήμη επηρεάζεται από τις κοινωνικές και τις θρησκευτικές συνθήκες.
1600 μ.Χ.	**Κέπλερ**	Αξιοποιώντας τις μετρήσεις του Μπράχε μιλάει για πρώτη φορά για ελλειπτική κίνηση πλανητών	Τροποποίηση του νέου μοντέλου με βάση τις παρατηρήσεις/τις μετρήσεις [illegible]
1610-1640 μ.Χ.	**Γαλιλαίος**	ο Γαλιλαίος με τη βοήθεια του τηλεσκοπίου απέδειξε ότι το ηλιοκεντρικό μοντέλο είναι το μόνο σωστό	Αποδείξεις με βάση παρατηρήσεις με χρήση τηλεσκοπίου ανατρέπουν το παλιό μοντέλο και επιβεβαιώνουν το νέο
....	....	....	....



Δραστηριότητα 1

Έχουμε στη διάθεσή μας μια ταινία αποτυπωμένη σε εικόνες (πλάνο πλάνο θα έλεγε ένας σκηνοθέτης), λείπει όμως το κείμενο.

⇨ Συμπληρώνουμε το κείμενο που πιστεύουμε ότι μπορεί να υπάρχει κάτω από κάθε εικόνα (πλάνο).

Δραστηριότητα 2

Παρακολουθούμε την ταινία _«Γαλιλαίος: Ηλιοκεντρικό σύστημα»._ Ταυτόχρονα έχουμε στη διάθεσή μας εικονογραφημένο το σενάριο της ταινίας (εικόνες και κείμενο).

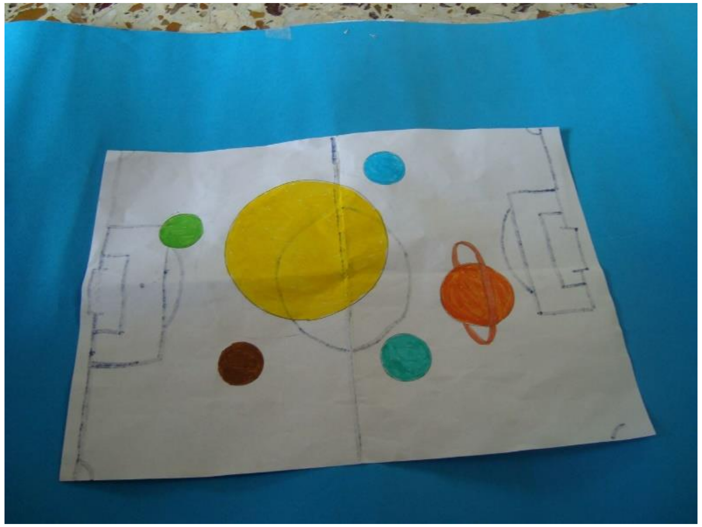
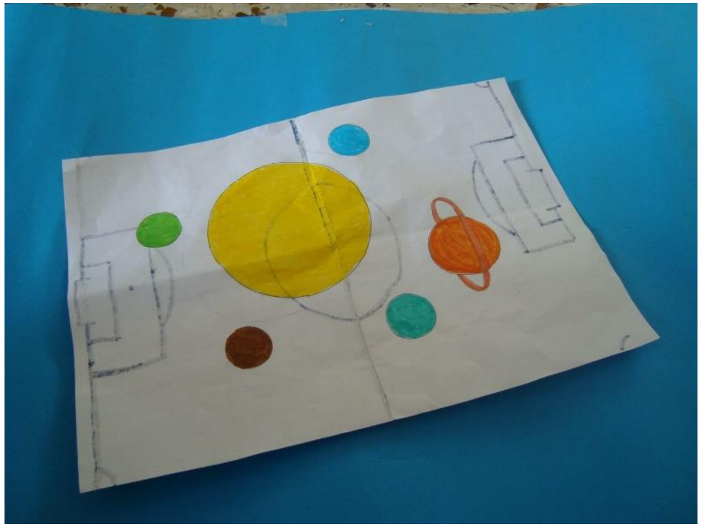
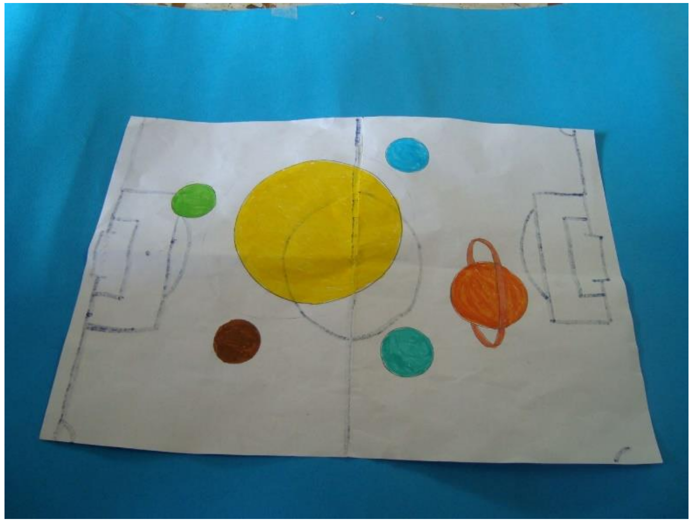
⇨ Τι πίστευαν οι άνθρωποι στην αρχαιότητα για τη σχέση Ήλιου και Γης; Που βασίζονταν για να υποστηρίζουν αυτή την άποψη;

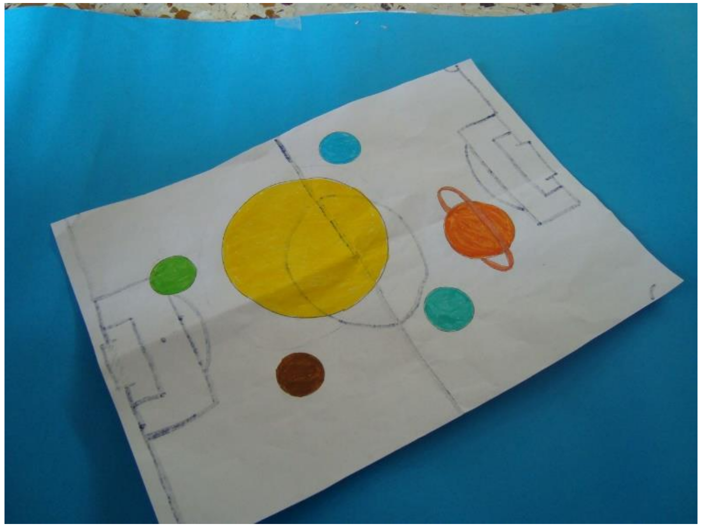
Πίστευαν ότι το κέντρο του κόσμου ήταν η γη γιατί παρατηρούσαν την κίνηση του ήλιου.

⇨ Πώς ονομάζεται στην ταινία το σύστημα για την Γη, τον Ήλιο και τους άλλους πλανήτες που πρότεινε ο Πτολεμαίος. Γράφουμε λίγα λόγια γι αυτό.

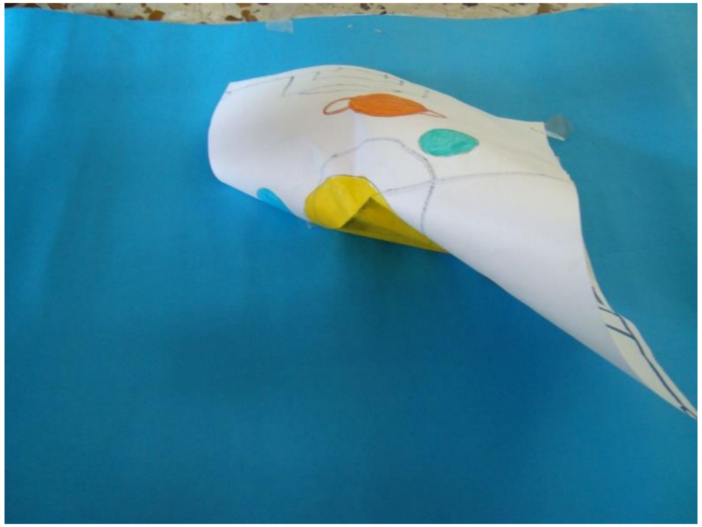
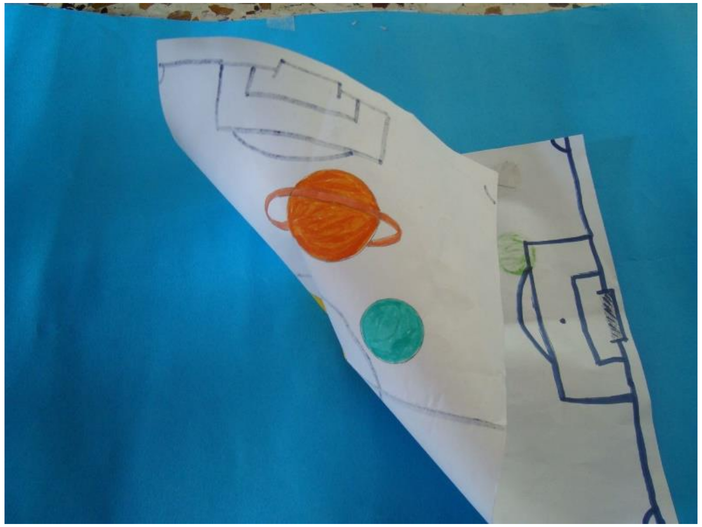
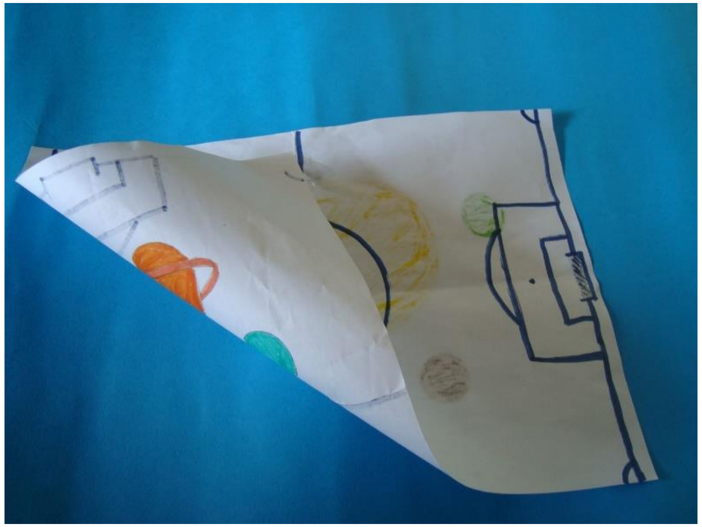
Α φάση: Προσανατολισμός (διάρκεια: 2 ώρες)

Pupils' worksheets

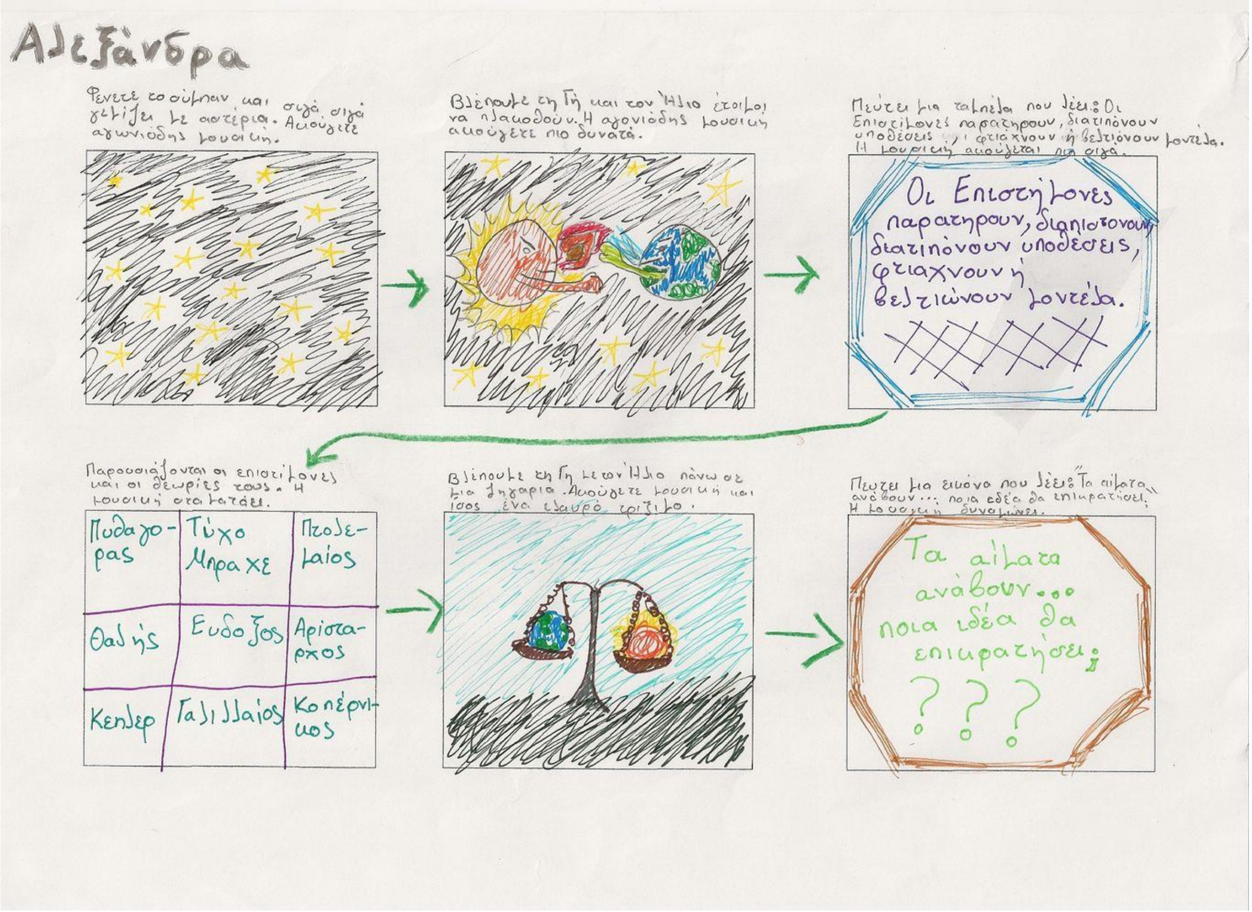




From the geocentric to the heliocentric system: A pupils flip book

Pupils' drawings (from pupils' flip books)



A pupil storyboard

10. Research concerning the implementation of the case study

The overall design of out research followed the following sequence:

Action 1: Research in the history of astronomy and HPS approaches and teaching strategies.

Action 2: The design of the teaching scenario

Action 3: The pilot implementation of the teaching scenario.

- Pre & post test
- Data collection during the implementation of the scenario (learning in the making)

Action 4: Analysis of the pilot implementation

Action 5: The redesign of the educational scenario

Action 6: The main implementation

- Pre & post test
- Data collection during the implementation of the scenario (learning in the making)

Action 7: Analysis of the main implementation

It has been done the implementation and the analysis of the pilot implementation of the teaching scenario in a 5th grade classroom in a public school in Athens in Greece.

The study examined this basic research questions:
Did the use of technique of animation by student help them to be acquainted with important aspects of the nature of science and also to be familiarized with the film language of animation?

Making a final comparative study the results that we had up to now from the application of the developed instructional material and activities and the focused research in the history of science concerning the geocentric-heliocentric debate, we come across a variety of aspects concerning the potential of the contribution of the history of science in science learning:

a) Change recorded in pupils' attitudes
Pupils participating in the implementation of the teaching scenario had never worked in a collaborative exploratory way so far. They had no previous experience on alternative teaching interventions different from the "traditional" ones mostly based on science textbooks. Not to mention that the use of history of science in science teaching has been totally new to them. Initially, as it is stated in the teacher's diary pupils rose questions such as: "Miss, are we obliged to learn these by heart?", or "should we write tests on this material?" (meaning the historical material). The students had an image of what a science lesson should be (the most important things being memorization, writing tests and working in a narrow context connected with activities focused only on content).

During the implementation of the teaching scenario there have been significant changes in pupils' attitudes. For example, many times pupils asked eagerly to work on the developed teaching scenario instead of doing science lessons in the context of the applied curriculum. Pupils' attitudes towards science lessons became more and more positive, they asked for more material and information coming from the history of science and showed genuine interest in their engagement with the geocentric-heliocentric debate, resulting with such a science course becoming their favourite activity in the primary school.

b) Changes recorded in pupils' language
In the beginning of the implementation, students used everyday terminology when discussing about the geocentric-heliocentric debate. During the application of the teaching scenario, pupils got involved actively in the production of language concerning this topic, got familiar to school science language and the language of animation. For example, in the initial phase of the implementation, pupils used general phrases such as "scientists think ..." and later expressions like "scientists observe", "scientist make hypotheses", "scientist make or improve models ....". Also, many pupils initially in their texts and their oral speech gave the same meaning to different scientific terms such

as "planet" and "model". During the course pupils gradually defined meanings and terms (e.g. star, retrograde motion, trajectory, rotation) and used them more correctly in their narratives of their movies. This gradual change on the way they spoke and wrote about the topic of study is reflected in the products developed by pupils such their story boards (e.g. figure 4), worksheets, scenarios digests, flip books, narrations in their movies and finally in the movies themselves.

c) Changes recorded on nature of science understanding

During their involvement with the activities developed based on the history of science pupils gradually became familiar with a variety of aspects of the nature of science and got introduced to the nature of the content and context of science, the nature of science-society interrelations, the nature of the development, evolution and methodologies of science as well as the values and attitudes fostered by science. The GNOSIS research model helped us analyze the developed films as the example presented previously. Some of the aspects of nature of science detected in pupil's films are the following:

a) New scientific interpretations can replace the old ones if new evidence supports them.

b) Scientists' argumentation as an intrinsic characteristic of the history of science.

c) Scientist use models to communicate their ideas.

d) Scientific ideas are affected by the social and cultural context.

An example of the last sentence is the understanding recorded on the effect of the social and cultural context in the formulation of scientific theories. This understanding was reflected in many of the animation movies produced by pupils, such as the one concerning the synthetic model of Tycho Brahe analysed above.

11. Further user professional development

http://facultyweb.berry.edu/ttimberlake/copernican/

The Copernican Revolution

A set of computer simulations and curricular materials for teaching the history of astronomy from Ancient Greece to Isaac Newton.

by Todd Timberlake, Associate Professor of Physics & Astronomy, Berry CollegeMount Berry, GA

http://www.teachersdomain.org/collection/k12/sci.ess.eiu.origins/

Origins and Evolution of the Universe, Teachers' Domain, WGBH Educational Foundation

http://www.teachersdomain.org/collection/k12/sci.ess.eiu.unicomp/

Composition of the Universe - Material concerning the understunding of the nature of science.

http://themes.protovoulia.org/?page=start&p=S.2.1
From the geocentric to the heliocentric system

http://brunelleschi.imss.fi.it/isd/eisd.asp?c=30832&xsl=3
Institute and Museum of History of Science, Florence, Italy

http://www.teachersdomain.org/special/kmedia07-ex/scitech.swift/
Science & Technology: SWIFT: Eyes Through Time

http://www.pbs.org/wgbh/nova/galileo/
Galileo's Battle for the Heavens

http://faculty.fullerton.edu/cmcconnell/Planets.html
Models of Planetary Motion from Antiquity to the Renaissance

http://www.learner.org/resources/series42.html
The Mechanical Universe...and Beyond

http://www.tki.org.nz/r/science/science_is/
The Science IS website has been created to help primary and secondary school teachers understand and integrate the Making sense of the nature of science (NoS) and Developing scientific skills and attitudes (DSSA) strands of Science in the New Zealand Curriculum (SiNZC).

www.siakasanimation.com

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