Effects of Augmented Reality on knowledge acquisition in comparison with traditional methods

Master Thesis

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Abstract

Augmented Reality (AR) is an attractive learning environment that can be used nowadays to foster learning, combining students' interactivity with 3D realistic visualizations. However, until now there are no clear findings claiming that AR can be a panacea for every educational case, as there are differences according to students' educational needs or preferences. The current study examines the knowledge acquisition that students gain from a lesson that is introduced with AR. Students from the 4th and 5th grades of Greek primary schools (*N=95*) learned about the Earth's transition from day to night and worked individually while completing a domain knowledge test, at the beginning and end of the lesson. Depending on the condition students were assigned to, students worked with either physical models, videos, or AR applications. The findings reveal no difference between conditions considering students learning and performance while learning. This signifies that there is not only one teaching method, from the ones examined, that is more advantageous for learning. This outcome indicates that better learning occurs not only from the educational medium used but also from the way that the medium is implemented. Further examination of AR's utilizations is needed in order to detect its strongest characteristics and ensure that it is introduced effectively in classroom.

Keywords: AR applications, physical models, videos, knowledge acquisition

Introducing Augmented Reality in Education

In the recent years technology has developed rapidly and its use is becoming more and more widespread, influencing the field of education. Researchers have made an effort to follow this technological progress and investigate how these technologies can be used effectively to foster knowledge acquisition and simplify complex teaching subjects, while improving the learning experience (Keller, Gerjets, Scheiter, & Garsoffky, 2004; Dunleavy, Dede, & Mitchell, 2009; Liarokapis & Anderson, 2010*)*. Augmented Reality constitutes such an innovative technology that is used in the classroom settings nowadays with potentials to enhance learning (Wu, Lee, Chang, & Liang, 2013). However, until now there are no clear findings that support the assumption that Augmented Reality can be a panacea for education, as there are different learning outcomes from its use, with respect to students' educational needs or preferences (Kerawalla, Luckin, Seljeflot, & Woolard, 2006; Radu, 2012). The focus of the current study is to examine the educational value of Augmented Reality and its impact on students' knowledge acquisition, in comparison with traditional educational methods.

Augmented Reality

Augmented Reality (AR) is a technology that enables the user to see virtual objects presented in the real environment, providing information that the user cannot detect with his/her own senses (Azuma, 1997). In order to characterize an environment as augmented, there are three elements that must exist at the same time. Firstly, the system should combine virtual representations and real environments in one view. Secondly, the system should be interactive in real time and thirdly, it should provide 3D images (Azuma, 1997).

AR can be categorized as an example of 'Mixed Reality' (i.e. when both real and virtual elements are perceived at the same time). Looking at Milgram and Kishino's (1994) "reality – virtuality continuum" (Figure 1) in which the different levels of "mixed reality" are presented, AR would be the first adaption from reality; the user is still interacting with the real environment and virtual elements that are added to this (Kerawalla et al., 2006).

Figure 1. Representation of the "virtual continuum" of Milgram & Kishino (1994) (*Valoriani, Giorio, & Pino, 2016).*

The interaction of both real and virtual world can be valuable for the conceptualization of abstractions and spatial relationships (Kerawalla et al., 2006). Moreover, AR has been found to be beneficial for teaching subjects that are impossible for students to experience firsthand in another way or to explore with their own senses (Shelton & Hedley, 2002; Kerawalla et al., 2006; Fleck & Simon, 2013; Wu et al., 2013).

Augmented Reality in education

Teaching abstract phenomena can be considered a challenging task for teachers as it is not easy to introduce in a classroom (Shelton & Hedley, 2002). This is because abstract phenomena involve domains that demand the visualization of complex spatial relationships from different perspectives, like certain processes and phenomena from physics, mathematics, geometry, chemistry, astronomy, biology and anatomy curriculum (Lee, 2012; Fokides & Foniadaki, 2017). For instance, the change of day and night on Earth requires the comprehension of the Earth-Sun relation that is difficult to achieve if students do not observe this relation through different angles and perspectives. This means, that students should be able to observe Sun – Earth's movements, their rotation, their enlightenment and compare their dimensions.

Usually, in education the use of models that represent abstract phenomena are used as an attempt to explain those phenomena in an easy way (Harrison & Treagust, 1998). Those physical models provide 3D visualizations and different perspectives of the presented subject and are assumed to help students' conceptualization. Traditionally educators select simple materials (such as balls, flashlights, sticks, tubs) to create these physical models. Though effective (Gobert & Buckley, 2010), a downside of these models is the lack of realism, as the used materials usually are similar only in systematic processes (Harrison & Treagust, 1998; Shelton & Hedley, 2002). AR would be a suitable alternative approach that can help overcome this problem. This is because AR simulations present realistic visualizations of the taught subjects and can avoid the metaphorical transitions between real and used objects.

However, the kind of model (physical or virtual) used for experimentation can be a matter of personal preferences or needs (Wu et al., 2013). An example of such could be that students may prefer the tangible interaction with simple materials instead of virtual models. Physical activity with the manipulation of physical models is considered a factor that influences the cognitive process and can also enhance learning (Marshall, 2007). However, there is evidence that AR is more beneficial than 3D physical models. For example, Fleck and Simon (2013) explored the use of both AR and physical 3D tangible models about the Earth-Sun-Moon relation on primary school students. Analysis of students' performance revealed better learning outcomes for students working with the AR rather than with the physical models. Students working with the physical models (i.e. balls and flashlight) experienced more difficulty with the movement and orientation of the devices (i.e. the balls or the table that had to be moved in relation to each other). Moreover, the abstract phenomena that they had to conceptualize and the devices that they had to move cognitively overloaded them. In contrast, the realism and the simple mobility of the virtual objects on the AR environment proved beneficial for students understanding (Fleck & Simon, 2013).

Realism. Fleck and Simon (2013) indicated that the realism of the virtual objects can foster students' understanding. Realism describes the level of similarity between the presented object and the picture that represents it. The similarity refers to shape, color, texture, motion and all features that describe an object (Scheiter, Gerjets, Huk, Imhof, & Kammerer, 2009). In the case of physical models, the objects that represent the abstract ones are metaphorical representations; meaning that a metaphor is used to represent some objects or phenomena. When the model is not a one-on-one representation of reality it leaves room for interpretation, and increases the chances that not all students understand the concept in the same way. In consequence, students may create alternative conceptions or achieve piecewise understanding of the taught subject, which could negatively influence their learning gains (Shelton & Hedley, 2002).In addition, the translation from the represented object to the real phenomena increases cognitive load as the learner has to build mental models and organize knowledge of abstract subjects (Paas, van Gog, & Sweller, 2010; Espiga & Blanca, 2014). According to cognitive load theory, to increase effectiveness, instructional methods should reduce extraneous processing (i.e. cognitive process due to poor instructional design) and manage essential processing (i.e. cognitive process due to the complexity of the material), so that learners have more cognitive capacity for the essential processing (Mayer, 2014). Hence, with realistic representations less cognitive load is generated than with metaphorical representations. Therefore, students have cognitive capacity available to invest in building knowledge. In the current study, in the AR applications used, the Earth-Sun's realistic representations enable students to see the real picture and use their cognitive capacity to conceptualize the content. Hence, learners are more likely to gain a deeper understanding and higher quality of knowledge (Scheiter et al., 2009; Espiga & Blanca, 2014).

Higher quality of knowledge indicates that the students can develop not only their factual knowledge (i.e. knowledge of terminology and simpler cognitive processes, like remembering basic parts, details and elements from the taught), but also their applied knowledge (i.e. knowledge that requires understanding of the content and signifies the ability to apply factual procedures in different learning context) (Krathwohl, 2002). Each educational material requires different cognitive processes. Consequently, the selection of the educational material used is essential for the quality and quantity of the gained knowledge.

Realistic representations, that can foster students' deep understanding, can be also introduced with educational videos. An educational video can be a powerful medium as it can provide representations in an attractive way (Zhang, Zhou, Briggs, & Nunamaker, 2006). Learning through videos enables the observation of real pictures with no need for further transition of information. However, videos usually provide 2D representations, in comparison with the aforementioned 3D models (i.e. real/physical or AR/virtual).

3D representations. Representations in 3D are simulated models that enable the examination of a variety of different perspectives of the presented objects (Wu et al., 2013). Urhahne, Nick, & Schanze (2009) explored the difference between 2D and 3D simulations on chemical learning on undergraduate and secondary students. The examination of students' performances, after their experimentation on the computer-based learning environment, revealed that 3D simulations were more beneficial than 2D simulations for chemical learning, but only for the secondary students and not the undergraduates. They reported that with inexperienced and incomplete mental models, students can improve their conceptualization when observing the taught subject in three dimensions. That is because 3D models provide visualization of different sides and perspectives. Hence the students can manipulate the models, observe and not imagine the different sides of the presented subject, reducing the possibility of cognitive overload of younger students, or students with lower spatial ability (Urhahne, Nick, & Schanze, 2009).Urhahne et al. (2009) research signifies that cognition is related to students' age. Hence, the selected educational methods should always correspond with the audience (Urhahne et al., 2009). Jaakkola & Veermans (2014) compared elementary students' comprehension on the electric circuit using concrete simulations and the combination of concrete and abstract simulations. They mentioned that students benefited more from the concrete simulations. Younger and inexperienced students are still developing their cognition. Hence, they need concrete approaches in order to grasp the learning concept and reduce potential cognitive overload. Consequently, the manipulation of concrete objects and the hands on experience, can benefit younger students' cognition (Uttal, Scudder, & Deloache, 1997; Jaakkola & Veermans, 2014).

Interactivity. According to constructivist learning theory, when learning occurs actively, through students' individual exploration or interaction with the learning environment, it is more valuable than the passive acquisition of information that is presented or explained to them by another person (Klahr & Nigam, 2004). Students' interactivity with the learning environment through the individual manipulation of the available material fosters their conceptualization of the content, their deep understanding and higher quality of knowledge (Klahr & Nigam, 2004). This happens because when learners interact with the content they construct mental models on their own, combining old models from their existing knowledge with the incoming information, and developing higher- order thinking (i.e. analysis, synthesis, evaluation) (Treagust, Chittleborough, & Mamiala, 2002; Michael, 2006). Hence, they are able to learn procedures and transfer them in different context, developing not only surface but also deep conceptual understanding (Sawyer, 2006).

Focus of this study

The above demonstrate that AR constitutes an attractive learning environment which provides realistic, 3D virtual models and interactivity of the student with the learning environment. Hence, AR can be promising in developing in depth understanding of the taught subject and higher quality of knowledge (Fleck, Hachet, & Bastien, 2015).

The present study aims to examine whether AR can lead to better learning outcomes and higher quality of knowledge when compared with traditional methods or whether it can be disruptive. The findings will illustrate whether it is educationally valuable for teachers to introduce AR in their lessons. In order to investigate the effectiveness of AR, AR is compared to two other types of traditional instructional materials: video and physical models. The selection of the compared educational material is based on their characteristics (i.e. realism, 3D representations, interactivity). These characteristics partially overlap with AR, as physical models provide 3D model and interactivity and videos provide realism. This enable us to distinguish which factors in AR (i.e. realism, 3D representations, interactivity) are likely to affect learning.

To examine that, students are experimenting in the same lesson using different material during the intervention. Hence a lesson using AR applications is compared with a lesson using physical models (i.e. balls and flashlights) and a lesson using video. The AR applications that are selected are open access simple AR applications that present 3D virtual images in the real environment (i.e. inside the classroom) that miss the real time interactivity with feedback annotations on students' work.

Aside from effects on overall learning, the instructional materials might differ in the quality of knowledge that students acquire. Consequently, aside from quantity, students' quality of gained knowledge might differ. Therefore, two types of knowledge will be compared: factual (lower quality) and applied (higher quality).

Furthermore, each instructional material (i.e. physical models, videos, AR apps) requires different cognitive processes. In order to distinguish whether age (as an indicator of cognitive development) affects students' performances with each material, the study will be conducted in two different grades of the primary school. The students' performances are compared per grade to investigate whether there are differences on students' knowledge acquisition from the use of each material.

The following research question is thus formed: To what extent do the AR environments benefit the students' knowledge acquisition in a way that is not achieved by a traditional lesson with the use of models of simple materials or the use of videos?

In order to investigate this research question the following sub-questions are formulated:

1. To what extent do the examined learning conditions differ on students' domain knowledge, according to the pre-test scores?
2. To what extent do the examined learning conditions differ on the quality of knowledge that students gain, according to students' performance on different type of questions?
3. To what extent does student grade affect the effect of the examined learning conditions on students' learning?

Method

Participants

Two randomly selected primary schools in Greece participated in this study, a private and a public one. In total 95 students from the 4th and 5th grade of both schools *(Mage= 9.6, SD= 0.63, age range 9 - 11 years old)* participated. These two grades were selected, as the students do not have prior knowledge on the subject that will be taught, and are old enough to work individually. Taking ethical concerns into consideration, only the students that had their parents' approval participated on the study.

Students of each grade to both schools were randomly divided over conditions: 33 students participated in the AR condition, 31 students in the Physical Model condition and 31 students in the Video condition. Six students were excluded from the data analysis, as they did not take the post-test. The random selection of the schools and the random division of the participants in each condition enable the characterization of the study as a randomized/true experimental design (Boudah, 2011). Students that had to work with the tablets on the AR condition were familiar with the devices and could use them easily. In one out of the two schools, the students had already experienced AR technology in other lessons.

Domain

The domain examined in this study is the solar system. The designed lesson is about planet Earth and its relation with the sun and moon. This subject is challenging and confusing for students, especially the younger ones (Vosniadou & Brewer, 1994; Fleck & Simon, 2013). Moreover, it is important part of the curriculum in primary schools in Greece.

The main learning subject of the lesson is the comprehension of the change of day and night on Earth. In order to clarify this subject, students will investigate Earth's and Moon's characteristics, in order to discover gradually their relation with the change of day and night. Hence, each part of the lesson examines a different learning goal from the ones that follow:

1. The student can name how, how fast and in which direction the earth moves
2. The student can reason about the connection between the earth's movement and the transition between day and night.
3. The student can name how the moon moves
4. The student can reason about the different lunar phases that are seen from Earth and how this happens

Instrumentation

For the needs of the study a domain knowledge test is designed and a lesson with assignments in which students experiment with different learning materials. The questions of the instruments (i.e. domain knowledge test and lesson) are the same for all conditions and are created in correspondence with the recommended educational material of the 6^{th} grade's book of Geography. The questions are also aligned with the teaching instructions and goals that are provided from the Greek Ministry of Education. Moreover, the questions and assignments were examined by a second teacher to ensure its appropriateness and were also tested on students that did not participate in the real study (The results from the pilot examination of the material and the adjustments that are made are presented in section 'pilot test'.). All those factors ensure the validity of the content of the instruments.

Domain Knowledge test. A domain knowledge test is provided to students in order to examine their domain knowledge in two different phases, before (pre-test) and after (post-test) the intervention. The test consists of four assignments which are two multiple choice sub-questions (questions 1A and 2A) and four open-ended questions (questions 1B, 2B, 3, 4) and are presented in Table 1. The questions align with the learning goals of the lesson (one question per learning goal). The students' answers were graded according to the coding scheme that was created and is presented in Table 1A in Appendix. The reliability of the test was examined with the Cronbach alpha. The pre-test's reliability is r=.433 and the post-test's reliability is r=.384.

Table 1
Domain knowledge test's Questions

No[a]	Question	Learning Goal [b]	Categorization
Q1A	Does the Earth move?	L1	Factual
Q1B	If yes, do you know how it moves?		
Q2A	Does the moon move?	L3	Factual
Q2B	If yes, do you know how it moves?		

Q3	The change of day and night is an everyday phenomenon. What happens to Earth and creates the day and night?	L2	Applied
Q4	While observing the moon from Earth, sometimes you see a full moon and some other times half of it, or even more of less than half moon. Why does this happen?	L4	Applied

[a] Questions 1 and 2 are divided in two parts (A and B) only for the evaluation of the answers and not on the students' worksheets [b] The learning goals are in line with the enumerated goals on the Domain of the Method section

Lesson. The lesson consists of assignments that students have to work on while interacting with the available material in each condition (i.e. physical models, video, AR apps). The 10 assignments consist of six multiple choice questions and sub-questions (1,2,3,5A,6,8A) and six open-ended questions (4,5B,7,8B,9,10) and are presented in Table 2. The questions align with the learning goals. However, as is seen in Table 2, Learning goal 3 (i.e. moon's movements) is not covered with an assignment but is provided as written textual information to all conditions, due to the limited time of the lesson. Hence, students are informed about the moon's movements and have to observe them during the intervention and explore their relation with the lunar phases. Students are supposed to explore that the sun's enlightenment does not affect only Earth but also the moon and consequently the lunar phases. The students' performances in the lesson's assignments were graded according to the coding scheme that is presented in Table 2A in the Appendix. The reliability of the lesson's assignments was tested with the Cronbach's α *r*=.419.

Table 2
Lesson's Questions

No	Question	Learning Goal [a]	Categorization
1	In which direction does Earth rotates around itself? Think that when Greece has noon (12:00), in New York the Sun rises and it is 5:00 in the morning, and in China the Sun sinks and it is 18:00 in the evening.	L1	Factual
2	If Greece has noon which continent will have noon after Greece? Asia or America?	L1	Applied
3	If Greece has noon, how many hours are needed in order to fulfill a rotation around itself and	L1	Applied

	have noon again?		
4	How is Earth enlightened?	L2	Factual
5A	Can all places in Earth be enlightened from the sun and have day at the same time?	L2	Factual
5B	Why?	L2	Applied
6	The duration of the day and night is not the same every day because Earth is in different position across the sun every day. How much time is it needed in order for Earth to fulfill a rotation around sun and be in the same position again?	L1	Applied
7	How is the moon enlightened?	L4	Factual
8A	Can all the parts of the moon be enlightened at the same time?	L4	Factual
8B	Why?	L4	Applied
9	If Greece has noon, find an area that has night at the same time.	L2	Applied
10	Can you find two areas that are not enlightened at the same time? Meaning, when the one has day, the other one has night.	L2	Applied

[a] The learning goals are in line with the enumerated goals on the Domain of the Method section

During the lesson, students gain learning through self-conducted investigations or examples, as the lesson follows a scientific discovery learning approach (De Jong, & Lazonder, 2014). At no point during the lesson did students receive feedback or help, as the evaluation of students' understanding has to be based only on their personal interaction with the available material, minimizing the influence of other factors. The questions in the lesson are the same for all three conditions. Meaning that between conditions only the medium differed (i.e. physical model, video, AR model).

It is important to mention that in all instruments (domain knowledge tests and lesson) the presented reliability is low. This is potentially due to the lack of homogeneity of the item's content (Tavakol & Dennick, 2011). In the current study, the tests include several different learning topics that cover the same domain but are not co-dependent. Meaning that they are related, but a better score on one does not automatically generate a better score on the rest.

Conditions.

Physical Model Condition. This condition uses simple materials as physical models in order to represent the Earth, Sun and Moon. The selected material is a flashlight that represents Sun, a ball that represents Earth and shows the image of a global map and a white ball that represents Moon. Both Earth and Moon are based on sticks that enable the users to rotate them around the sun (Figure 2). On the worksheet of this condition, written instructions explain what each object represents, providing some directions for their use. While the students interact with the 3D non-realistic physical models, they explore the relation between the different material and transfer their conclusions to the real phenomena.

Figure 2. Materials used in Physical Model condition

Video Condition. In this condition students watched a video about the taught subject. The video was created for the needs of the study, using parts from existing educational videos from YouTube. The video's duration is 3:05 minutes. The only sound that the video has is the explanation of the represented images (sun and earth) to avoid misunderstandings. The explanatory narration uses the researcher's voice, in lines with the Voice Principle, which mentions that learners learn better from a human instead of a machine's voice. It is decided to include narration for the explanation of the presented images instead of printing text, as according to the Modality Principle, learners learn better from a multimedia message with spoken text (Mayer & Pilegard, 2014). The explanatory narration and the images in the video are presented at the same time, following the Temporal Contiguity Principle of the Multimedia Learning Theory, which mentions that better learning can be achieved when corresponding text and pictures are presented at the same time (Mayer, 2014). The translation of the narration is provided in Appendix.

On the worksheet of this condition pictures of Earth's representation and the global map are included, as they are needed for assignments 9 and 10 of the lesson. The two pictures are provided only in the Video condition, as in the Physical Model condition students have a global map as a cover on the ball that represents Earth and the AR condition has an extra paper of global map that is used as a track for the AR application, as is explained next.

In this condition students were able to watch the 2D realistic representations of the phenomena, that introduced all information needed in the questions that followed. The students were watching the videos individually, and they could pause and play the video as many times as it was needed in order to find the related part of the video for each answer, a fact that improved their engagement in the learning process.

Augmented Reality Condition. This condition used two AR applications: Space 4D+ and Quiver. These applications were selected as they present realistic 3D visualizations (i.e. Earth and the solar system) in the real environment (i.e. inside the classroom), combining in one view the virtual and real elements. The students can rotate, start and pause the 3D realistic objects' movement, enabling their interactivity with the material. However, those two applications do not provide in real time feedback to the students decisions while working on the environment, hence students' engagement in the learning process is limited.

Students had the freedom to manage the time that they spent on each part of the intervention on their own. However, there were more questions that could be answered easily with the Quiver application, hence students spent more time on that application. These two applications can be downloaded for free and are both marker-based, which means they need a specific card with a track that is recognized from a camera in order to represent the virtual image in the tablet's screen (Wojciechowski & Cellary, 2013). Those cards were provided to all students.

For the present study the free version of Space 4D+ was used, which enables the basic version of the application including augmented elements that are required for the study. While opening this application with the use of the card called "solar system", the solar system is presented in front of the tablet (Figure 3). The sun is in the middle and all the planets and their physical satellites are moving around on their orbits. The students can observe Earth rotating around the sun and the moon rotating around Earth on its own orbit. The students are able to zoom in and zoom out if they need more details about those movements. With the use of the card called Earth, students are able to observe the Earth's rotation around itself and the moon's rotation around Earth (Figure 3). These representations enable the students to understand the Earth's and moon's movements and their relation with the sun. It is helpful for their understanding for the enlightenment of Earth.

Figure 3. Earth and Solar System presented on Space 4D+ app

Quiver uses a global map's drawing as a track to present Earth rotating around itself. Students are able to start and pause the rotation at any time by pressing the button. This application provides more choices to the user as it has four more buttons that present Earth with night light, with day light, with or without clouds, with the colors that the student used on the given drawing or with the real colors that can be seen from space (Figure 4). Quiver supports a clear 3D representation of Earth and students can recognize Earth's global shape, the differences of enlightenment between different places while Earth is rotating. The global map that is used as a track provides a more clear image of the continents and was useful for students on assignments 1,2,9,10 of the lesson.

Figure 4. Earth presented on the Quiver app

Pilot test

Before the real study, the material was tested on both 4th and 5th grade students. The pilot test indicated the needed adjustments on the first version of the instruments. Firstly, students were not able to complete all questions in a 45 minutes lesson. Hence, the lesson's duration was extended from 45 to 60 minutes and two questions were excluded from the domain knowledge test and one assignment from the lesson. From the first version of the domain knowledge test, two questions were excluded: "Earth, Moon and Sun are celestial objects to our solar system. Do you know if any of those moves in relation with another one?" and "Do all the places in Earth have day at the same time and night at the same time? How can you explain that?". Changes were also made in question 4 which on the first version was presented as follows: "The change of day and night is an everyday phenomenon. Why does this happen?".

On the lesson's assignments the following question was excluded "What moves does the Earth do?". Changes were made in questions 1 and 6, which on the first version were presented respectively as follows: "In which direction does Earth rotates around itself? Think that when Greece has noon (12:00), in New York the Sun rises and it is 5:00 in the morning, and in China the Sun sinks and it is 18:00 in the evening" and "On the 23rd of September the Sun enlightens the Earth in a way that day and night have exactly the same duration. From the next day the day starts getting smaller and the night bigger. How many days are needed in order for Earth to fulfill a rotation around the sun and be in the same position again? ".

The intervention (i.e. domain knowledge test and lesson) of the Video and AR conditions was firstly designed in an online environment named Graasp, using learning environments from the GoLab platform. Due to technical problems the digital material was not used and students in all three conditions worked on pen-paper procedure, filling their answers on the given worksheet.

Procedure

Prior to the data collection, the study was evaluated and approved by the Ethical Committee of the University of Twente. The study was completed in one session of a one hour lesson for each class. The first 10 minutes direct instructions were given to students in all three conditions by the instructor, to explain the goal and expectations and the use of each material. Following, the students had 10 minutes to fill in the domain knowledge test. Continuing, students had 30 minutes to experiment with their material and answer the lesson's assignments. Finally, they spent the last 10 minutes to complete the domain knowledge test again. The researcher mentioned the time that the students were supposed to work on each part of the lesson (i.e. pre-test, lesson, post-test), as all students were supposed to spend approximately the same time in each part.

Data Analysis

The analysis was conducted examining the students' answers to the domain knowledge test and the lesson's assignments. In order to determine the participants' performance, the total score of the domain knowledge before (pre-test) and after (post-test) the intervention and during the lesson were calculated, with each question consisting of a separate column, and each participant a separate row. Students' answers in each question were coded according to the coding scheme.

In the coding procedure the simple answer questions and open-ended questions were distinguished. Simple answer questions consisted of dichotomous questions (Yes/No), multiple choice questions, or open-ended questions where only one specific word provided the correct answer (i.e. assignments 9 and 10 of the lesson). The correct answers were provided in the answer key. For each incorrect answer the student received 0 zero points and 1 point was awarded for a correct answer. The open-ended questions, in which students were expected to reason their answer, were coded, indicating the participants score on each answer, with 0 for the incorrect answer up to the maximum points that each question can gain. The students could receive even 0,5 or 1,5 points according to their answer. The answer key was created after the examination of all answers, in order to create the necessary categories of the evaluation.

An example of the evaluation of some answers is presented. The third question of the domain knowledge test is "The change of day and night is an everyday phenomenon. What happens to Earth and creates the day and night?". The correct answer of this question is "Because the Earth rotates around its axis continuously, so the Sun enlightens only the part that is right across and has day and the part that is not enlightened by the Sun has night". This answer gains 2 points maximum as it contains two parts of information that the students should include in their answer. The first part is "Because the Earth rotates around its axis continuously" and gains 1 point. Students that answered "Because the Earth rotates" gained 0,5 point. The second part of the correct answer is "Because the Earth rotates around its axis continuously, so the Sun enlightens only the part that is right across and has day and the part that is not enlightened by the Sun has night" which also gains 1 point. Students that replied "Because the Sun enlightens different part of Earth each moment" gained 0,5 points. The coding scheme presents all questions with the coding answers and the categorization of the open-ended questions' answers.

All 95 participants' answers on the open-ended questions that needed reasoning (questions 1B, 2B, 3,4 of the domain knowledge test and 5B and 8B of the lesson) were rated by a second rater according to the coding scheme. The inter-rater reliability was examined with the Kendall's coefficient of concordance test, as the answers were graded on a continuous scale. Kendall's *W* showed that the two raters agreed W=.989 which shows an almost perfect agreement among them and indicates that the coding is sufficient reliable (McHugh, 2012).

The normality of the pre-test, post-test and lesson's scores for each condition was examined. A Shapiro-Wilk's test (p>.05) and the histograms, normal Q-Q plots and box plots revealed that the pre-test scores were not normally distributed for all conditions (Physical Model r<.001, Video r=.024, AR r=.023). The Physical Model condition's scores on the post-test and on the lesson were also not normally distributed (post-test r=.041, lesson r=.046). The two other conditions (i.e. Video and AR) in both post-test and lesson were approximately normally distributed (Video post-test r=.313, AR post-test r=.071 and Video lesson r=.114, AR lesson r=.134). The skewness and kurtosis measures of the tests in each condition, and their standard errors, are presented in Table 3.

Table 3

Skewness, kurtosis measures and their standard errors for students' scores per condition

	Pre-test		Lesson		Post-test	
Condition	Skew (SE)	Kurt (SE)	Skew (SE)	Kurt (SE)	Skew (SE)	Kurt (SE)
Physical Model	1.41(.42)	2.46(.82)	-.30(.42)	2.09(.82)	.95(.42)	1.38(.82)
Video	.21(.42)	-.84(.82)	-.24(.42)	-.75(.82)	.19(.42)	-.22(.82)
AR	.15(.40)	1.07(.79)	-.65(.40)	.29(.79)	-.08(.40)	1.16(.79)

Descriptive statistics (i.e. sample size, mean, standard deviation) are provided for each test (i.e. domain knowledge test, lesson). The Kruskal-Wallis H test was used for the comparison of students' prior knowledge in all conditions. This test was selected due to the lack of normality of the pre-test scores. The same test was also used to examine students' performance during the lesson with the intervention and to compare the learning gains of each different grade at school. In the cases that the p-value ($p<0.05$) indicated significant relation between the examined factors, post-hoc Bonferroni test analysis was used to detect the differences between the conditions.

Univariate analysis of covariance (ANCOVA) was used in order to examine students' performance on the post-test for all conditions, examining the factor of students' prior knowledge as a covariate. This covariate was included as according to a Pearson's correlation that was run, there was a strong positive correlation between prior knowledge and post-test scores, $r(93) = .505$, $p < .001$, with prior knowledge explaining 25% of the variation post-test scores. Finally, one-way MANCOVA analysis was conducted in order to examine the combination of the factual and applied questions' scores, on students' post-test scores and their performance during the intervention, with the control of prior knowledge.

Results

Table 4 presents descriptive statistics (i.e. means and standard deviations) for students' pre-test and post-test scores and their lesson performance per experimental condition. A Kruskal-Wallis H test was conducted to determine possible differences in students' prior knowledge between the conditions, examining the dependent variable of the pre-test scores and the independent variable of conditions. The results showed that students' prior knowledge was significantly different between the different conditions, $\chi^2(2) = 6.133, p = .047$. Subsequently, pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. This post hoc analysis revealed that the Physical Model (mean rank = 53.73) and Video (mean rank=52.23) (p=.044) condition significantly outperformed the AR condition (mean rank = 38.65) (p = .025). Consequently, prior knowledge is taken into account in the following analyses.

Table 4

Means and Standard deviations for students' scores by condition

Conditions	N		Pre-test Scores [a]	Lesson's scores [b]	Post-test Scores [a]
Physical Model	31	M	3.14	8.64	5.09
		SD	1.34	1.86	1.66
Video	31	M	2.95	8.16	5.04
		SD	1.10	1.59	1.76
AR	33	M	2.28	8.56	4.48
		SD	1.41	1.79	1.23

[a] Scores out of the maximum 15 points [b] Scores out of the maximum 14 points

Domain knowledge post-test results. Univariate analysis of Covariance (ANCOVA) was used to examine whether there were significant differences of students' learning gains between conditions, analyzing the dependent variable of post-test scores and the independent variable of conditions, with the control of prior knowledge as a covariate. There were no significant effects of the conditions on the post-test scores, F (2, 91) = 0.131, p= .877, η^2= .003. The covariate, prior knowledge, was significantly related to the students' post-test scores, F(1, 91) = 27.55, p< .001, η^2= .232.

Quality of knowledge. In order to test whether the quality of knowledge that students gain differs between conditions, a one-way MANCOVA was run with the combined dependent variables of factual and applied post-test questions and the conditions as the independent variable, with the control of prior knowledge as the covariate. The results showed that there was no statistically significant difference between the conditions on the combined dependent variables after controlling for prior knowledge F (2, 92)=1.27, p= .240, Wilks' Λ=1.388, η^2=.031. The descriptive statistics for each type of knowledge per condition are presented in Table 5.

Table 5

Means and Standard deviations for students' scores by condition per type of knowledge

		Lesson's scores		Post-test scores	
		Factual	Applied	Factual	Applied
	N	M (SD)	M (SD)	M (SD)	M (SD)
Physical Model	31	4.32(.79)	4.32(1.39)	4.19(1.24)	.90(.75)
Video	31	4.03(.60)	4.12(1.35)	4.45(1.45)	.62(.75)
AR	33	4.09(.85)	4.62(1.29)	3.90(1.10)	.57(.57)

Performance during the intervention. This section examines whether the conditions affected students' performance and understanding during the intervention. The overall mean of the performance during the intervention was 8.42 (range= 9.5, SD=1.71) out of the maximum of 14 points that can be gained. A Kruskal-Wallis H test was run to determine whether the dependent variable of students' scores during the intervention differentiated between conditions, which was the independent variable. The results showed that there is no significant differences on students' performance during the intervention between conditions, $\chi^2(2) = 1.269$, $p = .530$.

A one-way MANCOVA was run to examine differences on the quality of knowledge that is gained during the intervention. The MANCOVA showed that there was not statistically significant differences of the combined dependent variables of the factual and applied questions of the lesson between the independent variable of conditions, after controlling for the covariate of prior knowledge F (2, 92)=1.22, p= .301, Wilks' Λ= 946, η²=.027.

Differences per grade. This section examines differences on learning outcomes between the two different grades. Table 6 presents descriptive statistics on the domain knowledge test and on the lesson for the two different grades per condition. A Kruskal-Wallis H test was run to determine whether the dependent variable of students' post-test scores was significantly different between the students' school grade (i.e. 4th and 5th grade),which was the independent variable. The distribution of the post-test scores were significantly different between grades, $\chi^2(1) = 8.588$, p =.003, in favor of the 5th grade, as the mean score of the 5th grade students from all conditions outperforms the 4th grade's scores, according to Table 6.

Table 6
Means and Standard deviations for students' scores by condition per grade

		Pre-test scores		Scores during intervention		Post-test scores	
Grade		4th	5th	4th	5th	4th	5th
		M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)
Physical Model	31	2.7(.79)	3.56(1.63)	8.3(1.33)	8.96(2.24)	4.5(.86)	5.65(2.03)
Video	31	2.53(1.02)	3.4(1.03)	8.18(1.41)	8.13(1.81)	4.5(1.71)	5.63(1.67)
AR	31	1.53(1.06)	2.91(1.39)	8.03(2.13)	9.00(1.36)	4.13(1.34)	4.77(1.08)

Discussion

Discussion and Conclusions

The aim of the present study was to examine to what extent AR can influence students' knowledge acquisition in comparison with other educational methods, which are the Physical Models and Videos. The results from students' performance during and after the intervention did not indicate that there is one educational method, from the ones examined, that is more beneficial for students' learning. This finding differs from previous research in which AR environments proved to be more beneficial for students' learning in comparison with traditional methods (i.e. traditional teaching sessions or physical models) (Kerawalla et al., 2006; Fleck & Simon, 2013).

Although it would be expected that students working with the AR environment would outperform students working with the other two conditions this did not happen. More specifically, there were not better scores for students that interacted with the manipulation of 3D virtual or 3D physical models or for students that passively watched a video with 2D representations. Hence, interactivity with 3D material did not foster students understanding in the current study. A possible explanation for this outcome could be based on the type of interactivity that was provided with the selected material and the type of students' engagement that occurred. As already mentioned, the AR applications used in the current study lack the in real time feedback annotations on students' decisions on the environment. According to previous research, there are cases that simulations did not outperform other learning conditions in scientific discovery learning, because of lack of students' skills that were important while working on simulated environments (Plass & Schwartz, 2014). Skills can be improved with students' experiences, prior knowledge and maturation (Urhahne et al., 2009). These factors can be developed as students get older. In the present study, the comparison of the 4th and 5th students' performance showed that the 5th grade students outperformed the 4th grade students in all conditions. The outcome supports previous work that associated cognitive development with capability of comprehension of abstract phenomena (Urhahne et al., 2009).

Consequently, teachers should always adjust each educational material to the needs of each audience. In cases that students are inexperienced, as in the present study, more guidance is needed in real time with their performance on the environment. The design of each learning environment can influence students' learning gains (Plass & Schwartz, 2014). Hence, the effectiveness of each educational material corresponds to the way that is introduced in the educational context.

With respect to expected differences based on the realistic representations of the educational material, the findings did not indicate that the AR or video condition (that were realistic) benefited students understanding more than the Physical model condition (that were non-realistic). According to Hegarty (2004), realistic dynamic images cannot always lead to better understanding if there is not further explanation or aid for the students. Explanations or cues can lead students' attention to specific parts of the presented material, avoiding distraction from unimportant information that could cognitively overload the learner (Hegarty, 2004). Consequently, a possible explanation of the current study's outcome could be that students needed further explanation in order to benefit also from the realistic representations.

Overall there are no findings to support that students learnt better with one out of the three conditions. Although students' scores were higher in the lesson during the intervention than in the pre-test, their post-test answers did not indicate differences with those on the pre-test. Asking the same information in different time period helps students to recall the information, a process that can foster their deep understanding (Roediger & Butler, 2011). An explanation for not having improved scores in the current study could be based on the time that the pre-test, intervention and post-test took place. When the pre-test, intervention and post-test are presented in a short time period (that is one hour session), it is possible that the results will not be accurate, due to students' fatigue (Wang, Chang & Li, 2006).

In conclusion this study did not prove that there is one educational method, from the examined ones, that is better for students' knowledge acquisition or that can promote deeper comprehension of the taught subject. Every educational material can be more or less effective, but its effectiveness is determined by its implementation in the classroom (Liarokapis & Anderson, 2010; Plass & Schwartz, 2014). In the current study, the educational material used were not effective for students learning, as the way that the materials were used and designed did not foster students' learning. Consequently, the lack of different learning gains between the examined educational conditions may not be a matter of the material used but of the way that the material is introduced in each audience. AR is a promising technology that enables hands on experience for domains that students cannot experience differently. Teachers should adjust the AR environments used to their students' age and needs in order to achieve higher learning gains and a higher quality of knowledge.

Limitations and Future Works

An important limitation of the current study that prevents the generalization of the results and conclusions is that the reliability of the instruments used (domain knowledge test and lesson's assignments) were low, due to the fact that the questions on each learning domain were few. Future work could extent the domain knowledge test questions and the assignments during intervention in order to present more reliable findings.

According to the findings of the current study, the design of the AR intervention and the presented learning content did not engage students in the learning process in a way that could benefit them. Hence, future research should investigate the designed characteristics that could increase students' interaction with the AR environments, so that AR is used in an effective way for students' understanding.

Last but not least, the current study's results based on students' performances on the domain knowledge post-tests did not indicate that students improved their understanding after the implementation of each educational method. It would be recommended that future research could provide the domain knowledge post-test in another day after the intervention. In this way, students' performance would clarify their ability to reply to the same questions again, and examine the quality and quantity of their gained knowledge.

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Appendix

Coding Scheme of the pre-test/post-test and the lesson during intervention

Table 1A
Coding Scheme Domain Knowledge test

No	Question	Correct answer (Score)	Score Min-Max	Coding answers	Subcategories coding of open-ended questions
Q1A	Does the Earth move?	Yes (1p)	0- 1	0=No 1=Yes	
Q1B	If yes, do you know how it moves?	Rotation around itself (1p) , in 24 hours(1p) from right to left(1p) and Rotation around the Sun (1p), in 365 days and 6 hours (1p) in a cyclical rotation(1p)	0- 6	0=incorrect 0p	
				1=answer gaining 1p	1= around the sun 2= around its axis 3= in a cyclical rotation
				2=answer gaining 2p	4= around the sun and around its axis 5= around the sun in a cyclical rotation 6= around its axis in a cyclical rotation 7= around the Sun in one year 8= around its axis from right to left
				3=answer gaining 3p	9=around its axis from right to left in 24 hours 10=Around the sun in a cyclical rotation in one year

					11= around the sun and around its axis on a cyclical rotation
				4= answer with 4p	12= around its axis in 24 hours and around the sun in a cyclical rotation
					13= around the sun in one year and around its axis in 24 hours
Q2A	Does the moon move?	Yes(1p)	0-1	0= No	
				1=Yes	
Q2B	If yes, do you know how it moves?	Cyclical Rotation(1p) around Earth (1p) and rotation around itself(1p)	0-3	0=other (0p)1=answer gaining 1p	1= around Earth
					2= around its axis
					3= in a cyclical rotation
				2=answer gaining 2p	4= around Earth and around its axis
					5= around Earth In a cyclical rotation
					6= around its axis In a cyclical rotation
				3=answer gaining 3p	7= around the Earth and rotation around itself, in a cyclical rotation
Q3	The change of day and night is an everyday phenomenon. What happens to Earth and creates the day and night?	Because the Earth rotates around its axis continuously (1p), the Sun enlightens only the part that is right across has day and the part that is not enlightened by the Sun has night (1p)	0 -2	0=other 0p	
				1=answer gaining 0.5p	1= because Earth rotates
				2=answer gaining 1p	2= because the Sun enlightens different part of Earth each moment
					3=because the Earth rotates around its axis

					4= Because the Earth rotates continuously, so Sun enlightens only the part that is right across that has day and the part that is not enlightened by the Sun has night
				3=answer gaining 2p	5= Because the Earth rotates around its axis continuously, so the Sun enlightens only the part that is right across, which has day, and the part that is not enlightened by the Sun has night.
Q4	While observing the moon from Earth, sometimes you see a full moon and some other times half of it, or even more of less than half moon. Why does this happen?	Because the moon rotates around the Earth (1p) So according to the position is has in relation with earth and sun, the sun enlightens different part of it and we can see different phases of it (1p)	0- 2	0= incorrect 0p	
				1=answer gaining 0,5p	1= because the moon rotates
					2= because the Sun enlightens different part of the moon each moment
					3= because the moon rotates around Earth
				2=answer gaining 1p	4= Because the moon rotates. So according to the position is has in relation the sun, the sun enlightens different part of it and we can see different phases of it
				3=answer gaining 2p	5= Because the moon rotates around Earth. So according to the position is has in relation with Earth and Sun, the Sun enlightens different part of it and we can see different phases of it

Table 2A
Coding Scheme of the Lesson during intervention

No	Question	Correct answer(score)	Score Min-Max	Coding answers	Coding Subcategories of open ended answers
Q1	In which direction does the Earth rotates around itself?	From West to East(1p)	0-1	0=incorrect 1=correct	
Q2	If Greece has noon which continent will have noon after Greece? Asia or America?	America(1p)	0-1	0=incorrect 1=correct	
Q3	If Greece has noon, how many hours are needed in order to fulfill a rotation around its self and have noon again?	24 hours(1p)	0-1	0=incorrect 1=correct	
Q4	How is Earth enlightened?	By the sun (1p)	0-1	0=incorrect 1=correct	
Q5A	Can all the places in Earth be enlightened from the Sun and have day at the same time?	No (1p)	0-1	0= incorrect 1= correct	
Q5B	Why?	Because the Earth rotates(1p) and the sun enlightens different areas of the Earth one after the other(1p)	0-2	0= incorrect 0p	
				1= correct 0,5p	1= because Earth rotates
				2= correct 1p	2= because Earth rotates around its axis
				3= correct 1,5p	3= because the sun enlightens different part every time
				4=correct 2p \	4= Because Earth rotates and the sun enlightens different parts of Earth one after the other
Q6	How much time is needed in order for Earth to fulfill a rotation around sun and be in the same position again?	365 days 6 hours	0-1	0= incorrect 1= correct	
Q7	How is the moon enlightened?	From the sun	0-1	0= incorrect 1= correct	
Q8A	Can all the parts of the moon enlightened at the same time?	Nobe	0-1	0= incorrect 1=correct	

Q8B	Why?	Because the moon rotates around Earth [1p] and the sun enlightens different part of it depending on its position(1p)	0-2	0= incorrect 0p 1=correct 0.5p 2= correct 1p 3=correct 1,5p 4= correct 2p	1= because the moon rotates 2= Because the moon rotates around Earth 3= because the sun enlightens different parts of the Moon one after the other 4= Because the moon rotates and the sun enlightens different part of it depending on its position 5=Because the moon rotates around Earth and the sun enlightens different part of it depending on its position
Q9	If Greece has noon, find an area that has night at the same time.	multiple places can be evaluated as a correct answer if they are located in the opposite hemisphere	0-1	0= incorrect 1= correct	
10	Can you find two areas that are not enlightened at the same time? That means, when the one has day, the other one has night.	multiple answers can be considered correct, if they are located in different hemispheres	0-1	0= incorrect 1= correct	

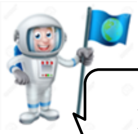
Translation of the Video's Narration

0:00:02 sec "This is Earth on Space. The rays are the Sun's light."
0:01:15 min "The white sphere that moves around the sun is the moon."
0:01:34 min "The different phases of the moon , as are seen from Earth."
0:01:40 min "The yellow line represents the sun's light. The blue line represents the moon's orbit."
0:01:57 min "The yellow line represents the moon's axis."
0:02:24 min "The white line represents the Earth's orbit around the Sun. Earth is like a sphere."
0:02:50 min "The global map is a paper representation of the Earth. The dark shadow shows the areas that are dark, that means they have night. "

Original and Translated Worksheets

Worksheet for Physical Model Condition.

Class:_________ Age:_______________



Hello! Today we will, explore our planet, Earth!

What do you believe?

Fill in your answer in the given space box.

1. Does the Earth move? If yes, do you know how it moves?

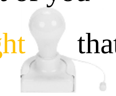
2. Does the moon move? If yes, do you know how it moves?

3. The change of day and night is an everyday phenomenon. What happens to Earth and creates the day and night?

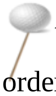
4. While observing the moon from Earth, sometimes you see a full moon and some other times half of it, or even more of less than half moon. Why does this happen?

Time to explore!

You have in front of you

☐ a fLashlight  that represents the sun, which lights Earth **continuously**

☐ a ball  that represents the Earth, which **rotation around the sun**

☐ a white ball  that represents the moon , **which rotates around Earth**

Use those three objects in order to understand the relation of Sun – Earth – Moon and answer the following questions.

1. In which direction does the Earth rotates around itself?

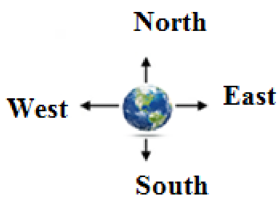
Think that when Greece has noon (12:00), in New York the Sun rises and it is 5:00 in the morning, and in China the Sun sinks and it is 18:00 in the evening.

☐ From West to East

☐ From East to West

☐ From North to South

☐ From South to North



2. If Greece has noon which continent will have noon after Greece? Asia or America?

☐ Asia

☐ America

3. If Greece has noon, how many hours are needed in order to fulfill a rotation around its self and have noon again?

☐ 12 hours

☐ 24 hours

☐ 48 hours

4. How is Earth enlightened?

5. Can all the places in Earth be enlightened from the sun and have day at the same time?

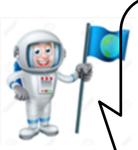
☐ Yes

☐ No

Why?

6. The duration of the day and night is not the same every day because Earth is in different position across the sun every day.

How much time is it needed in order for Earth to fulfill a rotation around the sun and be in the same position again?



Moon is the natural satellite of Earth and rotates around the Earth and around itself. It is also enlightened by the Sun. While observing the moon from Earth we can only see one part of the moon. This happens because the moon rotates around itself. If it wouldn't rotate around its axis we would be able to see all its different parts.

7. How is the moon enlightened?

8. Can all the parts of the moon be enlightened at the same time?

☐ Yes

☐ No

Why?

9. If Greece has noon, find an area that has night at the same time.

10. Can you find two areas that are not enlightened at the same time? Meaning, when the one has day, the other one has night.

Bravo! You made it! You have just finished your experiment.

Wait! We didn't finish yet! Answer again in those last questions.
Remember what you have learned!

1. Does the Earth move? If yes, do you know how it moves?

2. Does the moon move? If yes, do you know how it moves?

3. The change of day and night is an everyday phenomenon. What happens to Earth and creates the day and night?

4. While observing the moon from Earth, sometimes you see a full moon and some other times half of it, or even more of less than half moon. Why does this happen?

Thank you for your participation.

Worksheet for Physical Model Condition.-The original Document in Greek

Τάξη:____________ Ηλικία:__________

1. Κινείται η Γη; Αν ναι, μπορείς να περιγράψεις πως κινείται;

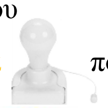
2. Κινείται η Σελήνη (δηλαδή το φεγγάρι); Αν ναι, μπορείς να περιγράψεις πως κινείται;

3. Η εναλλαγή της ημέρας και νύχτας γίνεται κάθε μέρα. Τι συμβαίνει στη Γη και δημιουργεί την ημέρα και τη νύχτα ;

4. Παρατηρώντας το φεγγάρι από τη Γη, άλλοτε το βλέπεις ολόκληρο (πανσέληνος), άλλοτε μισό ή ακόμη και μεγαλύτερο ή μικρότερο από μισό. Γιατί συμβαίνει αυτό;

Ώρα για εξερεύνηση !

Έχεις μπροστά σου

☐ μια **λάμπα**  που αναπαριστά τον **Ήλιο**, ο οποίος **φωτίζει συνέχεια** τη Γη.

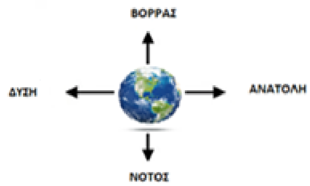
☐ μια **μπάλα**  που αναπαριστά τη **Γη** , η οποία **περιστρέφεται σε τροχιά γύρω από τον Ήλιο**

☐ μια **λευκή μπάλα**  που αναπαριστά τη **Σελήνη**, (δηλαδή το φεγγάρι) το οποίο **περιστρέφεται σε τροχιά γύρω από τη Γη**

Χρησιμοποίησε αυτά τα τρία αντικείμενα για να κατανοήσεις τη σχέση του Ήλιου, της Γης και της Σελήνης και να απαντήσεις στις επόμενες ερωτήσεις.

1. Με τι φορά περιστρέφεται η Γη;

Σκέψου ότι οταν η Ελλάδα έχει μεσημέρι (12:00), στη Νέα Υόρκη ο Ήλιος αρχίζει να ανατέλλει και είναι 5 (5:00) το ξημέρωμα και στη Κίνα ο Ήλιος αρχίζει να δύει και είναι 6 (18:00) η ώρα απόγευμα.



☐ από τη Δύση στην Ανατολή (από τα δεξιά στα αριστερά)

☐ από την Ανατολή στη Δύση (από τα αριστερά στα δεξιά)

☐ από το Βορρά στο Νότο (από πάνω προς τα κάτω)

☐ από το Νότο στο Βορρά (από κάτω προς τα πάνω)

2. Εάν η Ελλάδα έχει μεσημέρι, ποια ήπειρος θα έχει μεσημέρι μετά από την Ελλάδα; Η Ασία ή η Αμερική;

☐ Η Ασία

☐ Η Αμερική

3. Εάν η Ελλάδα έχει μεσημέρι (12:00), πόσες ώρες θα περάσουν μέχρι να ολοκληρώσει μια περιστροφή γύρω από τον εαυτό της και να έχει ξανά μεσημέρι;

☐ 12 ώρες

☐ 24 ώρες

☐ 48 ώρες

4. Πώς φωτίζεται η Γη;

5. Μπορούν όλα τα σημεία της Γης να φωτίζονται την ίδια στιγμή από τον ‘Ηλιο και να έχουν ημέρα ταυτόχρονα;

☐ Ναι

☐ Όχι

Γιατί;

6. Η διάρκεια της ημέρας και της νύχτας δεν είναι ίδια κάθε μέρα, διότι η Γη βρίσκεται σε διαφορετική θέση απέναντι από τον ήλιο κάθε μέρα.

Πόσος χρόνος χρειάζεται για να ολοκληρώσει η Γη μια περιφορά γύρω από τον Ήλιο και να βρεθεί στην ίδια θέση ξανά;

☐ 200 ημέρες και 6 ώρες

☐ 365 ημέρες και 6 ώρες

☐ 500 ημέρες και 6 ώρες

Το **φεγγάρι (ή αλλιώς Σελήνη)** είναι ο φυσικός δορυφόρος της Γης και **περιστρέφεται σε τροχιά γύρω της.** Κοιτώντας το φεγγάρι από τη Γη βλέπουμε πάντα μόνο μια πλευρά του φεγγαριού.

Αυτό συμβαίνει γιατί το φεγγάρι **περιστρέφεται γύρω από τον εαυτό του.** Εάν δεν περιστρεφόταν γύρω από τον εαυτό του θα βλέπαμε όλες τις πλευρές του.

7. Πώς φωτίζεται το φεγγάρι;

8. Μπορούν να φωτιστούν όλα τα σημεία του φεγγαριού ταυτόχρονα;

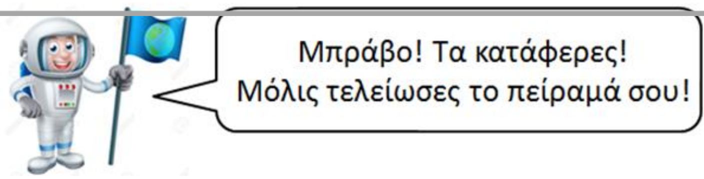
☐ Ναι

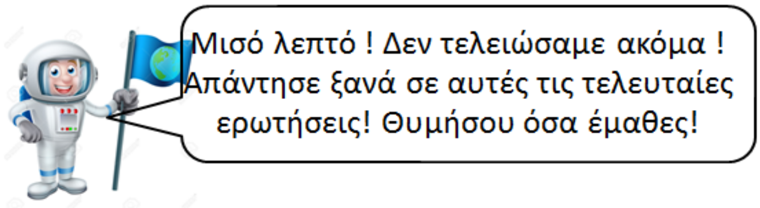
☐ Όχι

Γιατί;

9. Εάν η Ελλάδα έχει μεσημέρι, ανάφερε μια περιοχή που θα έχει νύχτα την ίδια στιγμή.

10. Μπορείς να σημειώσεις δυο χώρες που δεν φωτίζονται ταυτόχρονα; Δηλαδή που όταν η μια έχει ημέρα, η άλλη θα έχει νύχτα.





1. Κινείται η Γη; Αν ναι, μπορείς να περιγράψεις πως κινείται;

2. Κινείται η Σελήνη (δηλαδή το φεγγάρι); Αν ναι, μπορείς να περιγράψεις πως κινείται;

3. Η εναλλαγή της ημέρας και νύχτας γίνεται κάθε μέρα. Τι συμβαίνει στη Γη και δημιουργεί την ημέρα και τη νύχτα ;

4. Παρατηρώντας το φεγγάρι από τη Γη, άλλοτε το βλέπεις ολόκληρο (πανσέληνος), άλλοτε μισό ή ακόμη και μεγαλύτερο ή μικρότερο από μισό. Γιατί συμβαίνει αυτό;

Ευχαριστώ για τη συμμετοχή σου

Worksheet for the Video Condition.

Note: Only the Lesson questionnaire is presented here, as the pre-test and post-test (which are the first and last page of the paper) are the same in all three conditions.

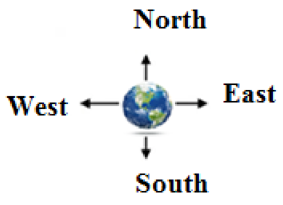
Time to explore!

Watch the video and answer to the following questions.

1. In which direction does the Earth rotates around itself?

Think that when Greece has noon (12:00), in New York the Sun rises and it is 5:00 in the morning, and in China the Sun sinks and it is 18:00 in the evening.

- ☐ From West to East
- ☐ From East to West
- ☐ From North to South
- ☐ From South to North



2. If Greece has noon which continent will have noon after Greece? Asia or America?

- ☐ Asia
- ☐ America

3. If Greece has noon, how many hours are needed in order to fulfill a rotation around its self and have noon again?

- ☐ 12 hours
- ☐ 24 hours
- ☐ 48 hours

4. How is Earth enlightened?

5. Can all the places in Earth be enlightened from the sun and have day at the same time?

- ☐ Yes
- ☐ No

Why?

6. The duration of the day and night is not the same every day because Earth is in different position across the sun every day.

How much time is it needed in order for Earth to fulfill a rotation around the sun and be in the same position again?

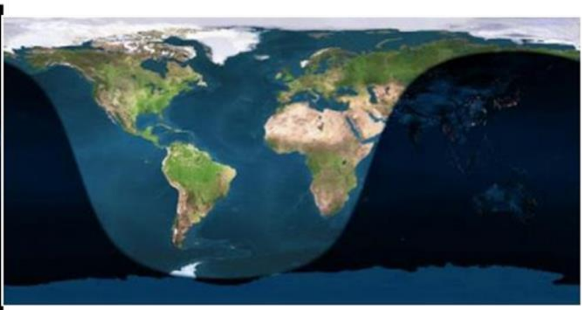
Moon is the natural satellite of Earth and rotates around the Earth and around itself. It is also enlightened by the Sun. While observing the moon from Earth we can only see one part of the moon. This happens because the moon rotates around itself. If it wouldn't rotate around its axis we would be able to see all its different parts.

7. How is the moon enlightened?

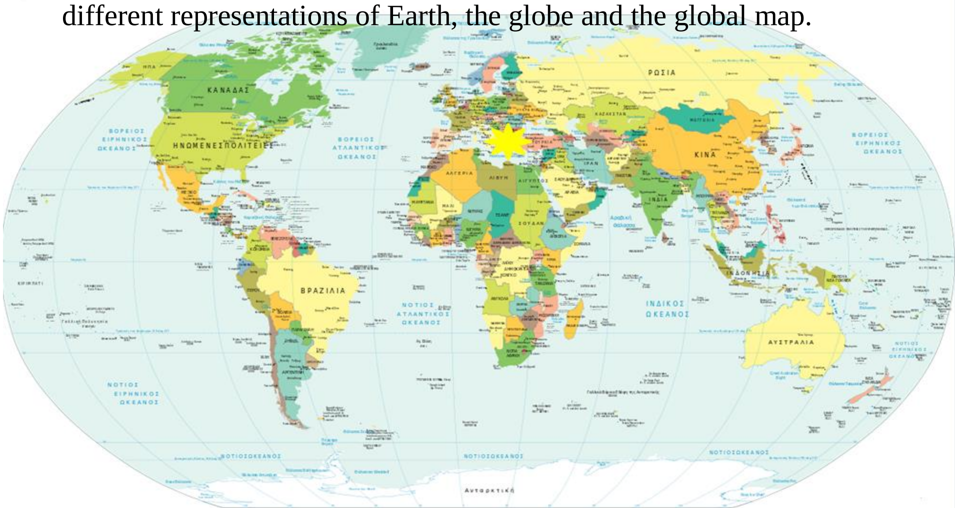
8. Can all the parts of the moon be enlightened at the same time?

- ☐ Yes
- ☐ No

Why?

You can see in the picture how different areas are when they have day and night in two different representations of Earth, the globe and the global map.



9. If Greece has noon, find an area that has night at the same time.

10. Can you find two areas that are not enlightened at the same time? Meaning, when the one has day, the other one has night.

Bravo! You made it! You have just finished your experiment.

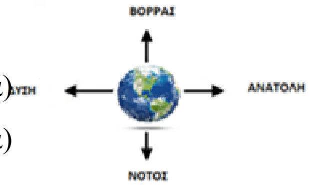
Lesson’s worksheet for the Video Condition-The original document in Greek

Ώρα για εξερεύνηση !

Παρακολούθησε το βίντεο και έπειτα απάντησε στις ερωτήσεις.

1. Με τι φορά περιστρέφεται η Γη;

Σκέψου ότι οταν η Ελλάδα έχει μεσημέρι (12:00), στη Νέα Υόρκη ο Ήλιος αρχίζει να ανατέλλει και είναι 5 (5:00) το ξημέρωμα και στη Κίνα ο Ήλιος αρχίζει να δύει και είναι 6 (18:00) η ώρα απόγευμα.



☐ από τη Δύση στην Ανατολή (από τα δεξιά στα αριστερά)

☐ από την Ανατολή στη Δύση (από τα αριστερά στα δεξιά)

☐ από το Βορρά στο Νότο (από πάνω προς τα κάτω)

☐ από το Νότο στο Βορρά (από κάτω προς τα πάνω)

2. Εάν η Ελλάδα έχει μεσημέρι, ποια ήπειρος θα έχει μεσημέρι μετά από την Ελλάδα; Η Ασία ή η Αμερική;

☐ Η Ασία

☐ Η Αμερική

3. Εάν η Ελλάδα έχει μεσημέρι (12:00), πόσες ώρες θα περάσουν μέχρι να ολοκληρώσει μια περιστροφή γύρω από τον εαυτό της και να έχει ξανά μεσημέρι;

☐ 12 ώρες

☐ 24 ώρες

☐ 48 ώρες

4. Πώς φωτίζεται η Γη;

5. Μπορούν όλα τα σημεία της Γης να φωτίζονται την ίδια στιγμή από τον ‘Ηλιο και να έχουν ημέρα ταυτόχρονα;

☐ Ναι

☐ Όχι

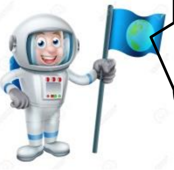
Γιατί;

6. Η διάρκεια της ημέρας και της νύχτας δεν είναι ίδια κάθε μέρα, διότι η Γη βρίσκεται

σε διαφορετική θέση απέναντι από τον ήλιο κάθε μέρα.

Πόσος χρόνος χρειάζεται για να ολοκληρώσει η Γη μια περιφορά γύρω από τον Ήλιο και να βρεθεί στην ίδια θέση ξανά;

- ☐ 200 ημέρες και 6 ώρες
- ☐ 365 ημέρες και 6 ώρες
- ☐ 500 ημέρες και 6 ώρες



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Αυτό συμβαίνει γιατί το φεγγάρι **περιστρέφεται γύρω από τον εαυτό του.** Εάν δεν περιστρεφόταν γύρω από τον εαυτό του θα βλέπαμε όλες τις πλευρές του.

7. Πώς φωτίζεται το φεγγάρι;

8. Μπορούν να φωτιστούν όλα τα σημεία του φεγγαριού ταυτόχρονα;

- ☐ Ναι
- ☐ Όχι

Γιατί;


Στην εικόνα μπορείς να δεις πως φαίνονται οι περιοχές που έχουν ημέρα και νύχτα σε δυο διαφορετικές απεικονίσεις της Γης, την υδρόγειο σφαίρα και τον παγκόσμιο χάρτη.

9. Εάν η Ελλάδα έχει μεσημέρι, ανάφερε μια περιοχή που θα έχει νύχτα την ίδια στιγμή.

10. Μπορείς να σημειώσεις δυο χώρες που δεν φωτίζονται ταυτόχρονα; Δηλαδή που όταν η μια έχει ημέρα, η άλλη θα έχει νύχτα.

Worksheet for the AR Condition.

Time to explore!

-**Open** the **Quiver** application, tapping in this image.

-**Press** the orange circle with the butterfly.

-**Focus** the tablet on the paper - map. *Make sure that the whole map can be seen by the tablet's camera.*

Press here to see Earth with the paper-map colors

Daytime on Earth

Night time on Earth

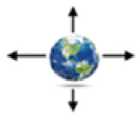
Press here to start or stop the Earth's rotation.

Add or remove the clouds.

1. In which direction does the Earth rotates around itself?

Think that when Greece has noon (12:00), in New York the Sun rises and it is 5:00 in the morning, and in China the Sun sinks and it is 18:00 in the evening.

- ☐ From West to East
- ☐ From East to West
- ☐ From North to South
- ☐ From South to North



2. If Greece has noon which continent will have noon after Greece? Asia or America?

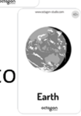
- ☐ Asia
- ☐ America

3. If Greece has noon, how many hours are needed in order to fulfill a rotation around its self and have noon again?

- ☐ 12 hours
- ☐ 24 hours
- ☐ 48 hours

- **Open** the **Space 4D+** application pressing this image.
- Put the **solar system** card in front of the tablet.
- Can you see that the Sun and the planets are in front of you? Can you find Earth?

- Put the **Earth** card in front of the tablet in order to see Earth and the moon.



4. How is Earth enlightened?

5. Can all the places in Earth be enlightened from the sun at the same time and have day?

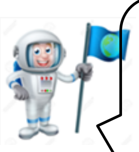
☐ Yes

☐ No

Why?

6. The duration of the day and night is not the same every day because Earth is in different position across the sun every day.

How much time is it needed in order for Earth to fulfill a rotation around the sun and be in the same position again?



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7. How is the moon enlightened?

8. Can all the parts of the moon be enlightened at the same time?

☐ Yes

☐ No

Why?

Open again the Quiver application and answer the following questions.

9. If Greece has noon, find an area that has night at the same time.

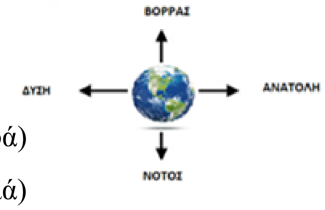
10. Can you find two areas that are not enlightened at the same time? Meaning, when the one has day, the other one has night.

Worksheet for AR Condition- The original document in Greek

Ώρα για εξερεύνηση !

1. Με τι φορά περιστρέφεται η Γη;

Σκέψου ότι οταν η Ελλάδα έχει μεσημέρι (12:00), στη Νέα Υόρκη ο Ήλιος αρχίζει να ανατέλλει και είναι 5 (5:00) το ξημέρωμα και στη Κίνα ο Ήλιος αρχίζει να δύει και είναι 6 (18:00) η ώρα απόγευμα.



☐ από τη Δύση στην Ανατολή (από τα δεξιά στα αριστερά)

☐ από την Ανατολή στη Δύση (από τα αριστερά στα δεξιά)

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2. Εάν η Ελλάδα έχει μεσημέρι, ποια ήπειρος θα έχει μεσημέρι μετά από την Ελλάδα; Η Ασία ή η Αμερική;

☐ Η Ασία

☐ Η Αμερική

3. Εάν η Ελλάδα έχει μεσημέρι (12:00), πόσες ώρες θα περάσουν μέχρι να ολοκληρώσει μια περιστροφή γύρω από τον εαυτό της και να έχει ξανά μεσημέρι;

☐ 12 ώρες

☐ 24 ώρες

☐ 48 ώρες

4. Πώς φωτίζεται η Γη;

5. Μπορούν όλα τα σημεία της Γης να φωτίζονται την ίδια στιγμή από τον 'Ηλιο και να

έχουν ημέρα ταυτόχρονα;

- ☐ Ναι
- ☐ Όχι

Γιατί;

6. Η διάρκεια της ημέρας και της νύχτας δεν είναι ίδια κάθε μέρα, διότι η Γη βρίσκεται σε διαφορετική θέση απέναντι από τον ήλιο κάθε μέρα.

Πόσος χρόνος χρειάζεται για να ολοκληρώσει η Γη μια περιφορά γύρω από τον Ήλιο και να βρεθεί στην ίδια θέση ξανά;

- ☐ 200 ημέρες και 6 ώρες
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Το **φεγγάρι (ή αλλιώς Σελήνη)** είναι ο φυσικός δορυφόρος της Γης και **περιστρέφεται σε τροχιά γύρω της.** Κοιτώντας το φεγγάρι από τη Γη βλέπουμε πάντα μόνο μια πλευρά του φεγγαριού.

Αυτό συμβαίνει γιατί το φεγγάρι **περιστρέφεται γύρω από τον εαυτό του.** Εάν δεν περιστρεφόταν γύρω από τον εαυτό του θα βλέπαμε όλες τις πλευρές του.

7. Πώς φωτίζεται το φεγγάρι;

8. Μπορούν να φωτιστούν όλα τα σημεία του φεγγαριού ταυτόχρονα;

- ☐ Ναι
- ☐ Όχι

Γιατί;

Άνοιξε ξανά την εφαρμογή Quiver και απάντησε στις επόμενες δυο ερωτήσεις.

9. Εάν η Ελλάδα έχει μεσημέρι, ανάφερε μια περιοχή που θα έχει νύχτα την ίδια στιγμή.

10. Μπορείς να σημειώσεις δυο χώρες που δεν φωτίζονται ταυτόχρονα; Δηλαδή που όταν η μια έχει ημέρα, η άλλη θα έχει νύχτα.