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THE DESIGN AND DEVELOPMENT OF AN ICT-ENHANCED MODULE CONCERNING DENSITY AS A PROPERTY OF MATERIALS APPLIED IN FLOATING / SINKING PHENOMENA

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ABSTRACT
This research is part of a project designed to promote children's interest both in Science and scientific careers. The project focuses on the specific domain of Materials Science (i.e., the materials around us, their everyday applications and properties). In our research we designed and developed a 10 hour module for studying the density of materials commonly found in the environment, as well as hi-tech materials, and applied it in floating / sinking phenomena. Moreover, in this module, learning the control of variables strategy, as well as aspects of modelling, and the nature and role of models are all promoted, to create an inquiry learning environment of different guidance level. The module is enhanced with Information and Communication Technologies (ICT), namely, multimedia and simulation environments, a visual model for the introduction of density, plus real experiments. It has been implemented in the 5th class of Primary School (10 –11 year olds). In this paper we present the development and evaluation of the pilot module's phase. The results show relative success in the conceptual part of the module, but moderate success in the procedural.

KEYWORDS
Property of materials, density, floating and sinking, teaching-learning environment, inquiry learning, modelling.

INTRODUCTION

In this paper, we describe the design and the pilot implementation of our module concerning the concept of density as a property of materials, according to the main aim of the project "MATERIALS SCIENCE". Density is an abstract concept: thus, to be understood by 5th grade students, it should be applied in a certain field of phenomena. Floating–sinking (f/s) phenomena were regarded as a fruitful field to implement density because: a) they are familiar and interesting for students of this age; and, b) the phenomenon outcome has an on/off character. Immediately, however, an issue arose regarding the students' conceptual difficulties with f/s: for example, "heavy bodies sink". To overcome this situation we decided to include the knowledge of factors affecting f/s phenomena. Initially, due to the experimental and inquiry character of the module, as an appropriate case, we considered the introduction of the Control of Variables Strategy (CVS) (Boudreaux et al., 2008). Furthermore, we introduced density through a semi-quantitative approach, using a visual model of density, named 'crowdedness model' (Smith, Snir and Grosslight, 1992), seeing that, according to the literature, density is a difficult mathematical concept for this age group. According to the literature, this could be enhanced if we presented aspects of modelling to the students, for example, the use of models (Justi & Gilbert, 2002; NRC, 2000, p. 20) as well as the nature and the role of models, for example, model deficiencies (Treagust, 2002). Fundamental understandings of scientific inquiry are both associated with the use and nature/role of models as well as the adoption of control of variables strategy (NRC, 2000, p. 20, 119, 163). These aspects of inquiry were also an objective of the project.

The design issues of the module are: (a) the didactical transformation of the content to be taught: the concept of density introduced by a visual model of dots in the unit of volume (crowdedness model), applied in the field of f/s phenomena. The scenario of the salvage of a sunken ship as a technological problem led to the driving question of the study; (b) the use of both guided and open inquiry approach; (c) the introduction of aspects of the nature/role of models to the students for them to have a more integrated view of the inquiry scientific method; and (d) the use of both hands-on and simulated labwork tasks to facilitate the study of scientific and technological knowledge.

In this paper, first, we focus on the main elements of each of the four design issues and, thereafter, we present and discuss a representative number of results, aiming to prove the effectiveness of the module, while concurrently marking down indicative modification implications for the next phase of the module's implementation.

DESIGN ISSUES OF THE MODULE

The didactical transformation of the content to be taught

Researchers who have studied student conceptions of density (Smith et al., 1992) consider that the difficulty in learning the notion of density is rooted in the fact that students appear to have already developed an alternative conceptual framework about matter. This framework is composed of quantities in which the raw scientific notions of weight, volume and density coexist. In this case, the difficulty students experience is mostly qualitative and conceptual and not quantitative. The non-differentiation between weight and density is evident in floating and sinking settings (Fassoulopoulos et al., 2003). Smith et al. (1992) adopted the view propounded by Smith, Carey & Wiser (1985) who believe that young children express primary views on complicated notions like density. In addition, according to the literature, students seem to have a strong visualization of f/s phenomena, which they explain and describe in terms of macroscopic natural properties, for example, weight, length, volume (Rowell & Dawson, 1977; Smith et al., 1985; Kawasaki, Herrenkohl & Yeary, 2004; Havu, 2005). Relevant research (Driver et al., 1994; Fassoulopoulos et al., 2003; Pnevmatikos et al., 2006) has shown that 5-15 year old students formulate their estimation concerning both the density of fluids and the floating of solid objects in water by taking into account the following: (i) the dimensions of vessels in which floating takes place - for example, students argue that in narrow vessels fluids are denser because they are more compressed and solid objects are pushed to the surface regardless of their relative density to the water; (ii) the weight of the bodies - for example, few students refer to weight in relation to size of bodies; (iii) the depth of water; (iv) the existence of hollows; and (v) the shape of the floating object. These results seem to reveal the problem of dovetailing teaching density with f/s.

The technological aspect of material properties is also a further demand of this project. We started the module design recognizing that we live in a world more complicated and technological than natural and simple. Our students utilize new technologies – computers, mobile phones - while many of their games are technological and electronic applications. Moreover, they constantly hear about new car models, genetically modified foods, and so on. It is, therefore, necessary to help students become aware of the fact that behind this complicated technological world, there are hidden physical laws and concepts, as density is in the present research. Moreover, according to Krajcik (2001) "*students who have an integrated understanding can apply their understanding to solve problems in a variety of situations and contexts*." (p. 10). Indeed, a number of research studies reveal that learning is contextually based and, as a consequence, students need to approach a range of different situations in order to understand the generality of scientific conceptions (Tao & Gunstone, 1999; Yeo et al., 1999).

To develop this kind of teaching module, we could assume our need for two discernible didactical transformations:

(i) The transformation of scientific knowledge (A), which means the transformation from formal scientific knowledge to knowledge understandable to students. According to the above findings, we decided to adopt a macroscopic approach of the property of density as a characteristic ("identity") of materials. The approach is based on the crowdedness visual model, where the number of dots represents the weight corresponding to the unit of volume of each material (Smith et al., 1992). In this way, we avoid the mathematical introduction of density - a very difficult task for students of that age (Rowell & Dawson, 1977; Smith et al., 1992). Density is represented by the number of dots in a cube of each material (figure 1). The size of this cube is considered to be one unit. Each material has a cube with the respective number of dots.

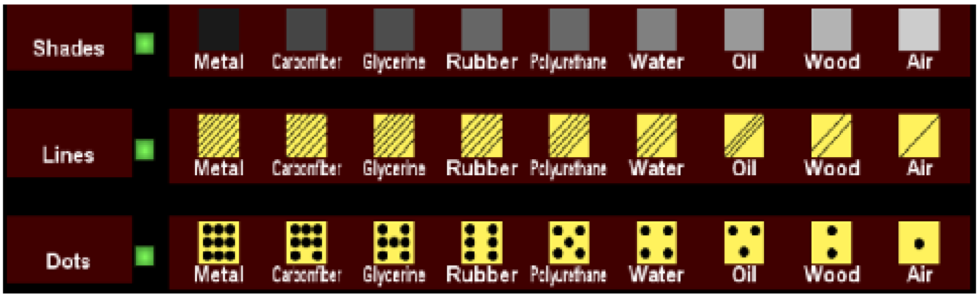

Figure 1: A screenshot from software depicting the visual model representing density

We study the density of materials commonly found in the environment (a piece of wood, plastic, and so on), as well as hi-tech materials (for example, fiber carbon, polyvinyl chloride). The qualitative approach of density includes two main instructional steps: (a) first, we introduce this crowdedness model for students to use in predicting / interpreting why some materials float or sink in specific kinds of liquid (3rd lesson); and, (b) second, we define that "density is a property of materials represented by this crowdedness model". After that, we ask them to compare the densities between different materials so as to predict/interpret f/s phenomena (4th lesson). In this phase, our aim is that students will "overcome" the visual model of density, by using the word "density" in their explanations. Following this instructional approach of density, we hypothesize that students will assume that density depends on the kind of material, and they will be able to predict/interpret f/s phenomena by comparing the densities between materials.

(ii) The transformation of technological knowledge (B) means the transformation from formal technological knowledge to knowledge understandable to students. The salvage of a sunken toy-ship is a representative example of this didactical transformation. Thus, students are asked to "find" the hidden property density behind a sunken ship (see figure 2).

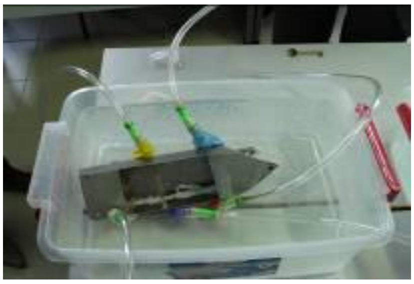

Figure 2: A sunken toy-ship in a water-filled tank.

Implementing guided and open inquiry in different contexts

In previous sections, we stressed that students have difficulties with f/s phenomena related to variables affecting these phenomena. We decided to confront these difficulties adopting an inquiry strategy: the

CVS (Toth et al., 2000; Kariotoglou, 2002).

However, it is noted "*that reasoning based on control of variables is challenging for students at all levels"* (Boudreaux et al., 2008). On the one hand, understanding of the control of variables strategy is considered important for students because it is in line with broader instructional objectives, namely, that students need to comprehend the scientific method as procedural knowledge and, furthermore, the nature of science as a process (Van Zee, 2006; Crawford, 2007; Boudreaux et al., 2008). On the other hand, related studies show that students - even teachers - confront difficulties in understanding the underlying reasoning of CVS (Krajcik, 2001; Boudreaux et al., 2008). As a consequence, it is proposed that: "*Students and teachers need guidance in undertaking inquiry. Trying to rush the inquiry process is like teaching someone to swim by throwing him into the deep end of the pool.*" (Krajcik, 2001, p.92). Taking into account the above consideration and the fact that Greek students in primary school have very limited experience of inquiry activities, we have designed and implemented different types of inquiry learning process, namely, guided and open, in two different contexts: technological and scientific.

First, students are familiarized with a technological problem, - the salvage of a sunken ship – attempting to find solutions to this problem (1st lesson). A driving question in a contextualized real-world environment is asked: "why did the cruise ship 'Sea-Diamond' sink?" This question serves the purpose of organizing and implementing all the other key questions and activities of the module, for example, "Why do ships sometimes sink?", "Which are the variables that affect f/s phenomena?" (Krajcik 2001, p.15-17). Following the first open key question, we approach CVS starting from highly structured teacher initiated activities to ones that are less so (NRC, 2000, p. 10; Wenning, 2005). Specifically, the teacher demonstrates an experiment, and asks probing questions for students to predict if a specific variable - the shape of the object - affects f/s phenomena. In addition, the teacher explains to students the inquiry process she/he has already followed (1st lesson). During the 2nd lesson, students control other variables possibly affecting f/s, namely, size of the object, width of the vessel, kind of liquid and the material the object is made of. Each time they have controlled a variable, we guide them with meta-cognitive reflection towards the specific procedure which they followed to control it. Specifically, the procedural knowledge includes four steps:

(a) We predict which variables possibly affect f/s;

(b) We decide how to test if a variable affects the phenomenon or not, (i) We keep all the remaining variables constant, and (ii) we conduct at least two tests in order to compare them;

(c) We test if this variable affects the phenomenon or not; and,

(d) We draw a conclusion.

A representative example of inquiry lab is the implementation of software tasks during the 2nd lesson, so that students check, for example, whether the width of the container affects floatation or not. They complete a worksheet with concrete questions and are guided to the conclusion that: the width of the container does not affect floatation. During the 5th lesson, we follow an 'applied hypothetical inquiry' process (Hanauer et al., 2009, p.14), that is, students try to salvage a toy-ship, as a real-world problem (technological problem, see figure 2). One of the main problems in adopting inquiry learning is that students tend to "*simplify inquiry tasks and seek 'right' answers rather than to investigate deeply*" (Kim et al., 2007). Thus, in tasks like the above, we decided not to give general instructions, thereby guiding the students to solve the problem, but ask them to analytically describe and offer reasoning for all the steps of their tasks. In this way, we lead our students to document their views, instead of searching for correct answers.

By following these different types of inquiry learning in two different contexts, scientific and technological, we hypothesize that students will be able to understand and implement the steps of CVS in different contexts.

Introduction of modelling, nature & role of models

Acts of modelling, according to Justi & Gilbert (2002) are the following: (i) model learning, namely, students learn existing models; (ii) model use for experimentation and prediction, namely, students use

existing models that are already taught; (iii) model revision, where students modify existing models to accommodate new purposes; and (iv) model production, when students construct new models.
In our module we focus on cases of modeling, corresponding to the above two first acts: model learning and model use. Specifically, we adopted the crowdedness visual model (see figure 1) in order to approach the concept of density (model learning, 3rd and 4th lessons). Furthermore, we asked students to use this model to predict and interpret f/s phenomena (see section above). For example, students, based on this model, predict if a piece of rubber floats in a water filled vessel (rubber has 6 dots per cubic area while water has 4 dots per cubic area).

Moreover, a discussion takes place during the 4th unit about the role of models, with the aid of two different models (a real 3-D and a sketch) of the heliocentric model, so as to change the idea that "models serve as exemplars" and conceptualize that "models serve as tools" (Penner et al., 1997), to explain, interpret and predict a phenomenon, for example, the day and night phenomenon. Students discuss with the teacher the constituents of the models and their utility and they are expected to learn that we could also have more than one model for celestial objects. Additionally, through this discussion, they are taught to learn two important facts concerning the nature of models: the first is that a model is a representation of a target and not its replica; the second is to adopt the idea of models as multiple representations (Treagust, Chittleborough & Mamiala, 2002). For example, they should realize that we can have a variety of visual models for the same property, for instance, density (see figure 1).

By following this teaching approach concerning models and modeling, we hypothesize that students will improve their understanding about basic aspects of the nature/role of models.

The reason we do not include model construction or revision activities is that both students and teachers in a Greek educational setting are unfamiliar with approaches that emphasize inquiry and model–based activities, so making it difficult to begin with extremely demanding modelling activities. Additionally, the content, which in our case is density in f/s phenomena, is too challenging for this age range, so we assumed that it might become too difficult if we interlaced this content with demanding model construction and revision activities.

The development of ICT and real labwork tasks
Students normally work in small groups carrying out hands-on experiments using multimedia and simulation environments as well as conventional laboratory apparatus. The development of these tasks is based on two types of didactical transformation of the content to be taught (see above). Namely, we develop tasks related to didactical transformation (A) and (B). Both the control of variables strategy and the concepts of density and model are mainly introduced through ICT tasks, whereas technology problems are mainly negotiated through real tasks. For example, in figure 1 we can see an example of a "room" of the software, where students get familiar with the crowdedness model of density (3rd lesson). In figure 2, we see an example of real tasks concerning the didactical transformation (B). Students try to find solutions in order to salvage this sunken ship (5th lesson).

Ultimately, the software constituted a single program for Microsoft Windows, making use of Game Maker software (http://www.yoyogames.com/gamemaker). In figure 3, we see a screenshot of the software where students are given the opportunity to control the variable of weight that potentially influences f/s (1st lesson).

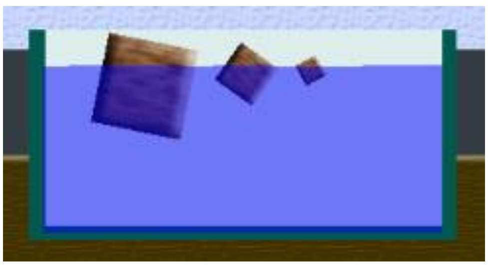

Figure 3: A screenshot of the simulated task for testing the variable of weight

RESEARCH METHODOLOGY

The pilot implementation of the module was conducted, at the 1st Experimental Elementary school in Florina, Greece. Twelve fifth-grade students (six girls and six boys, 10 – 11 years old) participated in the implementation. It was taught by the usual science teacher for the class in question, who, moreover, already has seven years of experience in this field, and cooperated with the research group in producing the module. The pilot study consists of five lessons of approximately 80 minutes each.

In this paper we aim to evaluate the effectiveness of the module "*by comparing the students' cognitive 'final state' with their cognitive 'initial state'*" (Méheut & Psillos, 2004) focusing on: (i) whether students overcome their cognitive difficulties concerning f/s phenomena and density as well, moving towards scientific ideas; (ii) whether students understand the steps of CVS; and, (iii) whether students understand basic aspects of the nature/role of models.

Pre- and post-questionnaires are the main research tools for our quantitative analysis of student learning outcomes. Video and audio recordings, as well as semi-structured clinical post-interview transcripts are used in a qualitative way to reveal the learning pathways of the students. Field notes by the researcher observing the lessons, student worksheets and their group work software records will enable us to triangulate assertions generated from both quantitative and qualitative analysis. In this paper, we focus on the evaluation of the results of pre- and post-questionnaires.

In that respect, the research questions related to questionnaires are:
(a) Which are the categories of student explanations about f/s phenomena, and how distant are they from the scientific one?
(b) Which are the categories of student understanding of density and how distant are they from the scientific one?
(c) To what extent do students master the steps of CVS?
(d) To what extent do students acquire basic aspects of the nature and role of models and abandon the recreational views?
The procedure that we followed for data collection using questionnaires is the following: one week before the implementation, students fill in the pre-questionnaire. Similarly, one week after the last lesson, students fill in the post–questionnaire. The pre-questionnaire consists of nine tasks, whereas the post- consists of thirteen, nine of which are common to both questionnaires.

RESULTS AND DISCUSSION

Results concerning student explanations about f/s phenomena

The results of the data analysis of the pre- and post-questionnaires, with respect to the explanations that students give for f/s phenomena are shown in table 1. Specifically, we see results from question 1a: "Will an anchor / a life buoy sink or float if we drop it in the sea? Please explain". The categories of this table are formed according to the students' answers and the review of relevant literature, as is presented in the relevant part of this article about the alternative conceptions that students have with respect to f/s phenomena. We see that some students' answers are 'teleological'; for example, "…a life buoy floats because it is supposed to save people…". Some students give explanations that are categorized as 'alternative idea' when, for example, their explanation is that "…it sinks because it is too big…" or "…it floats because it contains air…". The next category, 'rough view', corresponds to those students whose explanations are, for example, that "… the anchor sinks because it is made of iron and iron sinks…" and, according to literature, they are closer to the scientific than the alternative idea, by concentrating on the kind of material (wood, iron,...). The last category is the 'scientific view', where student explanations include comparisons between the densities of the object and the liquid it is dropped into: for example, "… the anchor sinks in water because the density of iron is less than that of water...". As we see in table 1, just before instruction, two students give 'teleological explanations/ justifications', whereas the remaining ten give answers that belong to the 'alternative idea' category. After instruction, only one gives 'teleological' explanations, four students' answers belong to the 'alternative idea' category, two belong to 'rough view' while five compare the densities of the object and the liquid.

Table 1: Explanations for f/s phenomena

	Question 1a	
	PreQuest	**PostQuest**
Scientific view	0	5
Rough view	0	2
Alternative View	10	4
Teleological explanations / justifications	2	1

Results concerning understanding of the concept of density

The results concerning student understanding of the concept of density are shown in table 2. For this categorization we had to analyze tasks from pre- and post-questionnaires as well as interview transcripts because the differentiation or non-differentiation between weight and density could not be revealed through the questionnaire tasks. The tasks used in the pre- and post-questionnaires were task 2a: "Write two phrases that most clearly express your thoughts each of which include the two words: density and material. You can put the words in the phrases in whichever order you wish"; task 2b, "In the picture below you see two wooden objects: a sphere and a cube. To create the sphere and the cube, we used the same type and quantity of wood. Note the two items contain the same quantity of wood. Which of the following phrases do you subscribe to: A. The wooden sphere has greater density; B. The wooden cube has greater density; C. Both objects have the same density; D. I don't know, Please explain your answer": and task 2c which was identical to task 2b, having though, instead of wooden objects, some objects made of iron. These tasks can reveal the ideas that students have about the concept of density. However, this is not a fact that we are able to discern from student answers to these questions, namely, whether they can differentiate between the two concepts, weight and density. On the other hand, during the interview, students could choose a balance or a tank filled with water so as to explore and compare weights and densities of several objects. If they used the balance to compare weight and the tank filled with water to compare the density of objects, we assumed that they did differentiate between weight and density. If they used both tools (balance and tank) without showing any comprehension concerning which of them we use to compare weight or density, then we assumed that they did not differentiate between these two concepts.

Table 2: Understanding of the concept of density

	Questions 2a, 2b, 2c, interviews	
	PreQuest	**PostQuest**
Scientific view	0	4
Rough view	0	3
Alternative View	11	5
Non-relevant views	1	0

The categories of this table concerning questions 2a, 2b, 2c and interview transcripts are created taking into account student answers and especially: if students a) assume that density depends on the material, for instance, give the following answer in task 2b: "…The right answer is C because both objects are made of the same material…"; and b) they differentiate between the concepts of weight and density as well, their view is categorized as 'scientific view'. If they refer to only the one of the two above statements, their view is categorized as 'rough view', assuming that density is considered by those students to be in a transitional phase between intensive (independent of the size of the object) and extensive (dependent on the size of the object) quantity. If they assume that density depends on the shape, volume or weight of the object, giving, for instance, the following answer in task 2b: "…The right answer is B because the wooden cube is bigger that the wooden sphere…", their view is categorized as 'alternative view'.

As we can see in table 2, just before instruction, one student gave a 'non relevant' answer, while all the remaining eleven students' answers were categorized as 'alternative' views. Following the instruction, there were no 'non-relevant' answer; four of the students' answers were categorized as 'scientific view', three as 'rough view', while only five as 'alternative view'.

Results concerning the ability to design experiments using the control of variables strategy
The results concerning student ability to design experiments using the CVS are shown in table 3. The categories of this table concerning question 4a: "In the water vessel we see a sunken ball made of plasticine. Could you change a factor so that the ball floats? Describe which factor you would change and the method you would use"; and 4b: "Describe what you will do to test if the change you suggest influences the phenomenon", are created, taking into account student answers and especially: if they intend to use relevant procedure to control the variable in question (two trials, keeping constant all the other variables, apart from that which is controlled, concurrently making observations) and if they confuse evidence with their own expectations. The categories concerning question 4c: "If you were to make any of your aforementioned suggestions, you might also draw a conclusion. Describe how you would come to this conclusion", are created, taking into account student answers: if they could describe the procedure of inferring a conclusion, taking into account the evidence that emanates from the observation. First, we will discuss part of table 4, particularly questions 4a and 4b. Prior to instruction, two students were unable to give an answer to these questions. Six of them seemed to confuse evidence with their own expectations ('alternative view 2' category) for instance, giving the following answer to question 4b: "… I believe that if I cut the ball into two pieces they will float ….". Two of them claimed that they could change and control two factors simultaneously ('alternative view 1' category), writing, for example, "… take a ball which is hollow and made of plastic…". Two of the students appeared to recognize that they should perform two trials and change only the variable that was under control ('partially scientific view' category), writing, for example, "… I will take half of the plasticine ball, I will drop it in the water and this way I will understand…". No one was able to give an answer that could be categorized as 'scientific view' (two trials, all other variables are constant, making observations).

Table 3: Ability to design experiments using the control of variables strategy

	(question 4.a, 4.b) Control of variable			**(question 4.c) Draw a conclusion**	
	PreQuest	**PostQuest**		**PreQuest**	**PostQuest**
Scientific view	0	1	**Scientific view**	0	0
Partially scientific view	2	3	**Rough view**	1	2
Alternative view 1	2	1	**Alternative view**	7	9
Alternative view 2	6	7	**No answer**	4	1
No answer	2	0			

After instruction, all of them give answers, while seven of them continue to confuse their own expectations with evidence. Only one proposes controlling two variables simultaneously, three of them seem to understand that they have to perform two trials and change only the variable that is under control and one student appears to recognize the importance of observation, saying, “I will make a ball from leaves of a tree, I will drop it in the water and I will see what happens…”. Concerning question 4c, before instruction, four students did not give any answer, seven others mentioned the conclusion or the procedure of controlling the variable instead of the procedure to conclude (‘alternative view’), and only one student mentioned the evaluation of the results of the experiment (‘rough view’). None of the students could give an answer that could be categorized as ‘scientific view’ (comparison of the results of the experiment). After instruction, students still fail to articulate the full hypothetic-deductive reasoning that underlies the use of CVS as a means of testing the role of a variable. Specifically, only two of them mention the evaluation of the results of the experiment (‘rough view’), while nine refer to the conclusion or the procedure of controlling the variable (‘alternative view’). One of the students is still incapable of supplying any answer at all.

Studying table 3 overall, we can conclude that although our students exhibit a partial improvement concerning the CVS, they still confuse evidence with own expectations. On the other hand, we notice a negligible change in the drawing of a conclusion. These results are in line with those of relevant research concerning not only elementary students (Toth, Klahr & Chen, 2000), but also adults (Boudreaux et al., 2008).

Results concerning understanding aspects of the nature and role of models

The results concerning the students’ understanding of the nature and role of models are shown in table 4. The categories in this table are created from a combination of five features in student answers. We seek to learn if they understand that: a) a model is a representation of a target; b) a model is not a copy of the target; c) a target can be represented by more than one model, d) a model helps explain or predict a phenomenon; and, e) that the function of models is recreational (in terms of beauty, aesthetics and having fun). Question 3a asks students to write the most representative phrase, in their opinion, including the word ‘model‘. Question 3b, on the other hand, asks them to decide and explain whether a photo and map of the city of Thessaloniki, as well as a tourist map of the prefecture of Thessaloniki are models or not. Student answers which all include a), b), c) and d) from the above features of models are categorized ‘scientific view’. Student answers with one or more of a), b), c) and d) from these features of models, are categorized ‘partial view’. Student answers comprised only of e) or e) and any of a), b), c) and d) features are categorized ‘recreational view’.

Table 4: Understanding features of the nature and role of models

	questions 3a, 3b	
	PreQuest	**PostQuest**
Scientific view	0	0
Partial view	0	5
Recreational view	12	7

All the students had a ‘recreational view’ before instruction. For example, one student writes: “… my sister is going to be a model when she grows up …”; and another: “…my father wants to buy the new Audi model…”. This is in line with Gilbert’s (1991) claim that “…many students believe that models serve primarily a recreational or instructional function, the use of which requires little or no creativity…”. After instruction, although there are five students who seem to have improved when, for example, making sentences (question 3a) using taught models (of a ship, the crowdedness model), seven students still continue to have a ‘recreational view‘. Furthermore, five students have improved, answering, for example, in question 3b, that they believe all three items (photo and maps) are models because “…they represent what they show…”. We assume that these students accept that a model is not a copy of the target, as well as that a target can be represented by more than one model since they accept that a photo and a map of the same town can be models of this town. According to these results, we realize that, although the number of students who could understand some of the features that comprise the nature and role of models, have increased after instruction, there are still many who continue to have the recreational alternative view about this concept. Undoubtedly, on this very important issue concerning the nature and role of models, we ascertain some appreciable improvement with respect to the number of students who attribute more features to the concept of model. Furthermore, we notice a considerable decrease (from twelve to seven) in the students holding the recreational view. Nevertheless, we consider the number of students still having this alternative view to be quite remarkable. The results, in line with relevant literature (Treagust et al., 2002), reveal the fact that students barely grasp even the basic features of the nature and role of models.

Concluding, the results show that the students make a significant improvement not only in the explanations that they give about f/s phenomena, but also in their understanding of the concept of density. These two knowledge fields constitute the conceptual knowledge of the module. On the contrary, the results concerning procedural knowledge (the CVS and the nature and role of models) of the module are limited. "*Scientific inquiry processes, if formally addressed at all, are often treated as an amalgam of non-hierarchical activities. There is a critical need to synthesize a framework for more effective promotion of inquiry processes among students at all levels"* (Wenning, 2005). Thus, the results are close to those expected, seeing that in a Greek educational setting procedural knowledge is not greatly emphasized. Consequently, neither teachers nor students are accustomed to focusing on such kinds of knowledge. The above findings will guide the researchers to initiate modifications in the module before its second phase of implementation: for example, by scaling the activities from the more to less guided, or by placing more emphasis on discussion about the nature and role of models. Such changes could give us the opportunity to ascertain if and to which level is it possible for students to acquire elements of procedural and scientific knowledge.

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