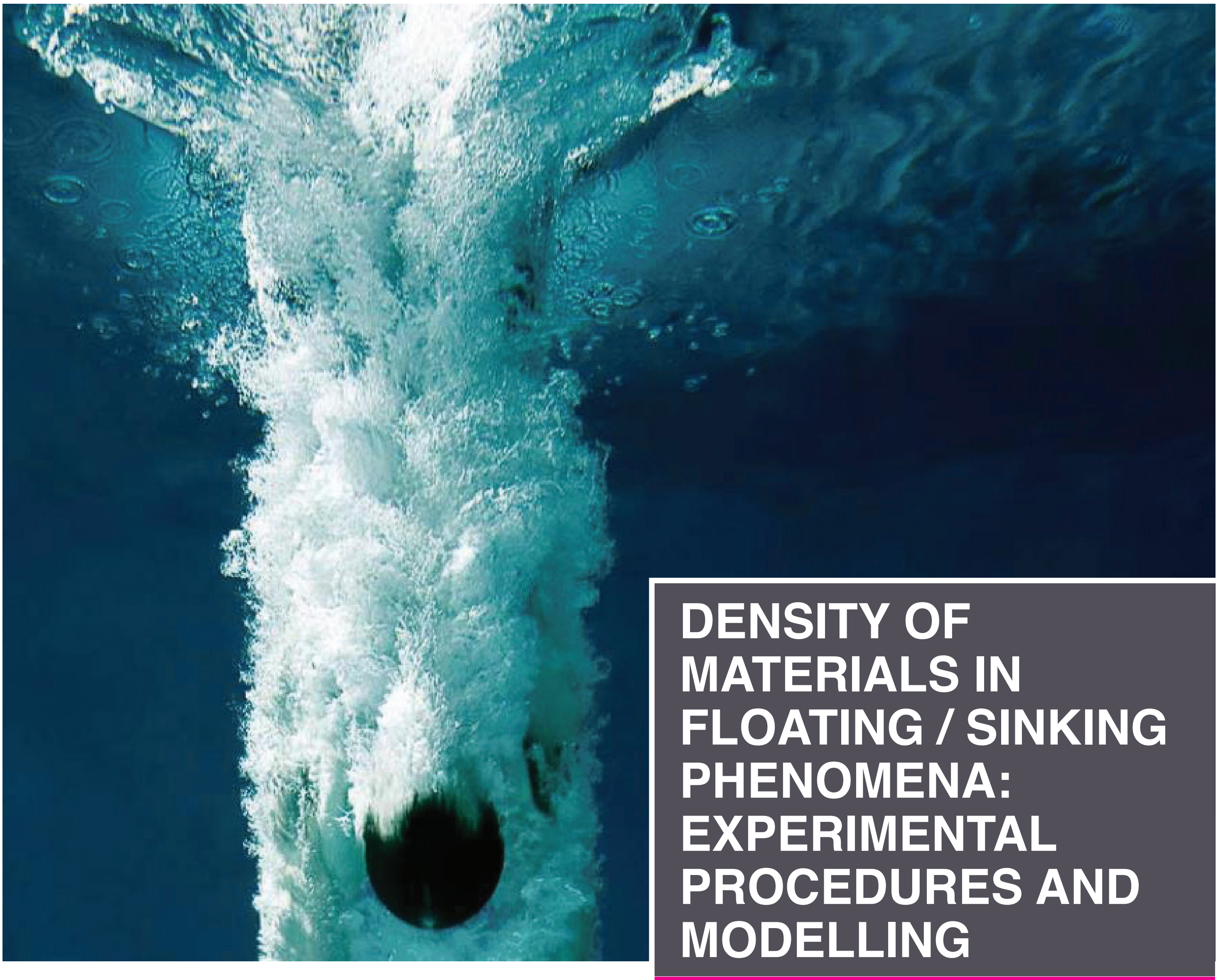

DENSITY OF MATERIALS IN FLOATING / SINKING PHENOMENA: EXPERIMENTAL PROCEDURES AND MODELLING

TEACHERS' MANUAL

ORIGINAL VERSION

MATERIALS SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS FOR THE DESIGN AND IMPLEMENTATION OF RESEARCH-BASED ICT-ENHANCED MODULES ON MATERIAL PROPERTIES

SPECIFIC SUPPORT ACTIONS

FP6: SCIENCE AND SOCIETY: SCIENCE AND EDUCATION

PROJECT COORDINATOR
CONSTANTINOS P. CONSTANTINOU,
LEARNING IN SCIENCE GROUP,
UNIVERSITY OF CYPRUS

PROJECT PARTNERS

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DENSITY OF MATERIALS IN FLOATING / SINKING PHENOMENA: EXPERIMENTAL PROCEDURES AND MODELLING

Design and development

University Team
Kariotoglou Petros
Kaskalis Theodoros
Malandrakis Georgios
Pnevmatikos Dimitrios
Spyrtou Anna
Zoupidis Anastasios

School Teachers
Blouchou Stefania
Kollini Kalliopi
Polatidou Theodora
Soultanis Konstantinos
Triantafillidou Reggina

Software development
Arvanitakis Ioannis

Other Contributors
Transfer, Implementation and Feedback

University Staff
Jan Jansson
Jari Lavonen
Veijo Meisalo

School Teachers
Jyri Jokinen

Peer review and feedback
Veijo Meisalo

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A: TEACHERS’ GUIDE

A: TEACHERS' GUIDE

1. INTRODUCTION

1.1. INTRODUCTION TO THE MODULE

The science education research group of the University of Western Macedonia is one of the 6 groups, from 5 European countries, which constitute the consortium of Materials Science project "University-school partnerships for the design and implementation of research-based ICT-enhanced modules on Material Properties" funded for the EU (Contract Number: SAS6-CT-2006-042942; 2007 – 09). This project is in the frame of the Science and Society project, FP6, the main aim of which is to change attitudes and interest of European students towards Science and Technology and for careers reasons. The main aim of the project Materials Science is to create a mechanism for integrating the results of science education research in school teaching practice for 10-15 year olds in the domain of Properties of Materials. Our group has been developed, applied and cyclically modified the module (or Teaching Learning Sequence) "Density of Materials in Floating / Sinking phenomena: experimental procedures and modelling"

1.2. THE RATIONALE OF THE MODULE

We decided to study density because:

- It is a prevalent concept in Science
- Pupils find it difficult to understand
- The LWG had experience in this issue

and to apply our module in Primary School, because in our School of Education, we prepare Primary school teachers.

After that we should select the field of applicability of this property. Otherwise, we should select the kind of phenomena which are appropriate for this property. Floating–sinking was regarded as a preferential field to implement density due to the pupils' age, the phenomenology of relative experiments and the on/off situation of the phenomenon outcome. Immediately though, an issue came up regarding the pupils' difficulties with floating–sinking e.g., "the heavy bodies sink". This complicated the situation somehow and intertwined the problem of teaching density with the one of teaching floating–sinking.

We know the cognitive difficulties students confront concerning floating / sinking (f/s), e.g. "… the heavier objects are sinking, while the lighter are floating …." For this reason we selected that students should find out by themselves the factors affecting f/s, so as to change their alternative views. It was this that led us to incorporate the study of parameters which affect floating–sinking and are directly connected to the procedure of separating and controlling parameters, in accordance to the demands of the project for inquiry learning.

In a similar way we have taken another important decision concerning the teaching of models and modelling skills to our students, mainly as a consequence of the use of a representation of density: "a cube with the dots", namely the crowdedness model (Smith, Snir and Grosslight, 1992). This decision came up as a result of our attempt to find a different way for introducing density apart of mathematical treatment which is extremely difficult for such age range students. The relevant literature suggests that to enhance introduction of models to primary students we should encounter some declarative knowledge about this issue (Schwarz and White, 2005).

Finally, we developed a module for the study of density of materials found easily in the environment (e.g., a piece of wood, glass, plastic, etc.), as well as hi-tech materials (e.g., fibber optics or carbon). Students use this property of the materials to predict and interpret mainly phenomena of floating – sinking of fluids / liquids in liquids. The module is enhanced with information and communication technologies (ICT) aiming to study the variables affecting floating-sinking. The module was implemented in the 5th class of Primary School (10 –11 year old students) in an inquiry - learning environment aiming at modelling of the scientific knowledge.

1.3. RELEVANCE OF THE MODULE

Greece is associated with the sea and navigation from the ancient years. The many islands and its connection for transportation as well as for tourism is very common issue for all Greeks independently their age. Due to these reasons the nautical accidents and the ship-wrecks are not rare, e.g. the accident of "Samina" (September 26, 2000) with 80 rank people, or dip of “Sea Diamond” (April 5, 2007) with 2 missing people. Both accidents had a big cover in TV all over Greece, but also worldwide. Consequently, we consider that the study of floating or sinking or the salvage of wreck could answer questions raised by every day events associated with the life of people. We think that such subject matter could create positive attitudes and interest for the students to study them.

We use the scenario of the sunk of a cruise – ship Sea Diamond, which had large media coverage on April 2007, to start the module in a technological environment. Then, we are going to the scientific study of the factors affecting f/s, as well as the introduction of density. Moreover, we propose the solution of practical – existing problems, associated with technological applications, with every – day materials, but also with materials of the new technology, when it is possible (fibber glasses and carbon). e.g. “Which is the proper solution (material), for coming – up a statue from the bottom of the sea?” We finish with a technology problem that of the salvage of a model ship

2. CONNECTION OF THIS MODULE TO OTHER MODULES IN PROJECT MATERIALS SCIENCE

Our Module is connected with the others of the Materials Science project with different ways or point of reference. There are some features which are common more or less across all the other modules, as following:

- the study of a basic property (density, sound attenuation, heat conductivity, magnetic interactions, light interactions with matter, ….) across different every day materials (wood, metal, plastic,….), as well as, new technological materials (fibber carbon, fibber optic)
- the inquiry approach to learning
- the use of ICT to facilitate inquiry learning
- the use of models and modelling activities

Moreover there are some features which are more common among our module and the module of some other groups. In particular the most important common feature with that of **AUTh’s** one is that of models. Both modules aim at the learning and application of existing models, e.g. the model for f/s in **Florina’s** module, the model of dielectric polarization in **AUTh’s** one.

The most important common feature with that of **Cyprus** module is the existence of a scenario. In both modules a scenario is used in order to motivate students and to help them to raise questions. The scenario in **Cyprus** case suggests students to develop a magnetic train, while in **Florina’s** case to salvage a ship-wreck.

The most important common feature with that of **Barcelona’s** and **Naples’s** modules is that in three cases the view of inquiry learning is adopted. In **Florina’s** case more gradually and qualitatively, while in the two other cases more open and quantitatively, due to the difference in students age range: 10-11 years old in **Florina**, 15-16 years old the others.

Moreover, **Barcelona’s** module has some more features in common with ours, e.g. the emphasis given in the distinction and control of variables affecting a phenomenon, as well as the importance that density has for both floating sinking phenomena and for the sound attenuation.

Finally, there are some features in common with the Finish module like the study of materials according to their properties, or the use of the approach POE (prediction – observation - explanation) in most of the activities.

3. BACKGROUND INFORMATION[1]

3.1. FLOATING AND SINKING

The phenomenon of floating / sinking (f/s) can be studied either by using the concept of density or the force of buoyancy.

3.2. DENSITY

The density of a material is defined as its mass per unit volume. The symbol of density is ρ (the Greek letter rho). Mathematically:

$$\rho = m / V$$

where: ρ is the density, m is the mass, V is the volume.

Different materials usually have different densities, so density is an important concept regarding buoyancy, metal purity and packaging. In some cases density is expressed as the dimensionless quantities specific gravity (SG) or relative density (RD), in which case it is expressed in multiples of the density of some other standard material, usually water or air/gas.

3.3. THE HISTORY OF DENSITY

In a well-known common story, Archimedes was given the task of determining whether King Hiero's goldsmith was embezzling gold during the manufacture of a wreath dedicated to the gods and replacing it with another, cheaper alloy. Archimedes knew that the irregularly shaped wreath could be crushed into a cube whose volume could be calculated easily and compared with the weight; but the king did not approve of this.

Baffled, Archimedes took a relaxing immersion bath and observed from the rise of the warm water upon entering that he could calculate the volume of the gold crown through the displacement of the water. Allegedly, upon this discovery, he went running naked through the streets shouting, "Eureka! Eureka!" (Greek "I found it"). As a result, the term "eureka" entered common parlance and is used today to indicate a moment of enlightenment. This story first appeared in written form in Vitruvius' books of architecture, two centuries after it supposedly took place. Some scholars have doubted the accuracy of this tale, saying among other things that the method would have

1. *Most of the information in this unit 3 comes from Wikipedia, the free encyclopaedia.)*

required precise measurements that would have been difficult to make at the time.

3.4. MEASUREMENT OF DENSITY

For a homogeneous object, the mass divided by the volume gives the density. The mass is normally measured with an appropriate scale or balance; the volume may be measured directly (from the geometry of the object) or by the displacement of a fluid. Hydrostatic weighing is a method that combines these two.

If the body is not homogeneous or heterogeneous, the density is a function of the coordinates

$$\rho(\vec{r}) = dm / dv$$

where dv is elementary volume with coordinates $\vec{r}$. The mass of the body then can be expressed as where the integration is over the volume of the body V.

$$m = \int_V \rho(\vec{r}) dv$$

A very common instrument for the direct measurement of the density of a liquid is the hydrometer, which measures the volume displaced by an object of known mass. A common laboratory device for measuring fluid density is a pycnometer; a related device for measuring the absolute density of a solid is a gas pycnometer. Another instrument used to determine the density of a liquid or a gas is the digital density meter - based on the oscillating U-tube principle.

The density of a solid material can be ambiguous, depending on exactly how its volume is defined, and this may cause confusion in measurement. A common example is sand: if gently filled into a container, the density will be low; when the same sand is compacted into the same container, it will occupy less volume and consequently exhibit a greater density. This is because sand, like all powders and granular solids contains a lot of air space in between individual grains; this overall density is called the bulk density, which differs significantly from the density of an individual grain of sand.

3.5. COMMON UNITS

The SI unit for density is:

- kilograms per cubic meter (kg/m³)

  Metric units outside the SI

- kilograms per litre (kg/L). At 4 °C, water has a density of 1.000 kg/L, making this a convenient unit at about the room temperature,
- kilograms per cubic decimetre (kg/dm³),
- grams per millilitre (g/mL),
- grams per cubic centimetre (g/cc or g/cm³).

3.6. CHANGES OF DENSITY

In general density can be changed by changing either the pressure or the temperature. Increasing the pressure will always increase the density of a material. Increasing the temperature generally decreases the density, but there are notable exceptions to this generalisation. For example, the density of water increases between its melting point at 0 °C and 4 °C and similar behaviour is observed in silicon at low temperatures.

The effect of pressure and temperature on the densities of liquids and solids is so small so that to be considered not compressible. In contrast, the density of gases is strongly affected by pressure. Boyle's law says that the density of an ideal gas is given by where R is the universal gas constant, P is the

$$\rho = \frac{MP}{RT}$$

pressure, M the molar mass, and T the absolute temperature.

This means that a gas at 300 K and 1 bar will have its density doubled by increasing the pressure to 2 bar or by reducing the temperature to 150 K.
Osmium is the densest known substance at standard conditions for temperature and pressure.

3.7. DENSITY OF COMPOSITE MATERIAL

Density (or mean density) of composite object which consisted from 2 materials, 1 and 2, is given by a formula like:

$$\rho = \alpha_1\rho_1 + \alpha_2\rho_2$$

where: ρ is the density of the composite material, ρ_1 and ρ_2 are the densities of materials 1 and 2, while α_1 and α_2 the relevant by weight contribution of the two materials into the object.

(I) (II) (III)

FIGURE 1. THE THREE DIFFERENT POSITIONS OF FLOATING/ SINKING

3.8. STUDY OF F/S USING DENSITY

If an object of density ρ_o, drops in a vessel containing a liquid of density ρl, then there are three positions for the object (figure 1):

I) the object is floating in the surface of the liquid: $\rho_o < \rho_l$,

II) the object is floating inside the liquid: $\rho_o = \rho_l$,

III) the object rests in the bottom of the vessel: $\rho_o > \rho_l$,

If the object is consisted form more than one materials, then we use the concept of the mean density, in the above formulas.

3.9. ARCHIMEDES' PRINCIPLE

Buoyancy is the upward force that keeps things afloat. The net upward buoyancy force is equal to the magnitude of the weight of fluid displaced by the body. This force enables the object to float or at least seem lighter.

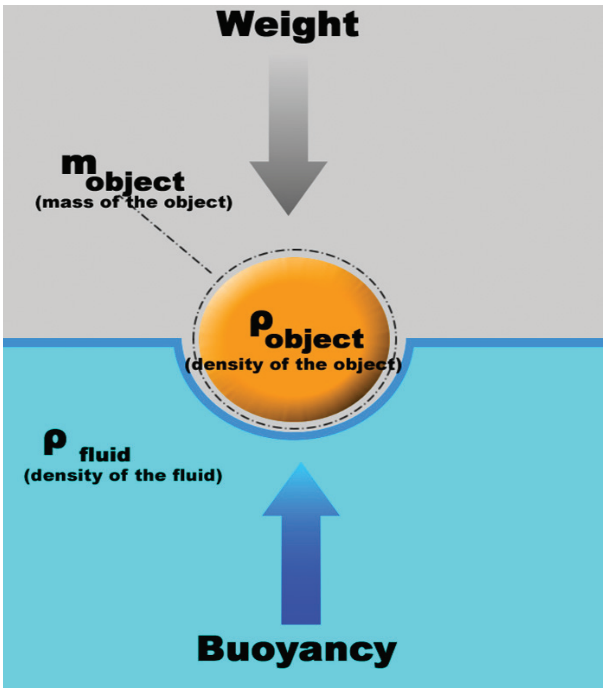


FIGURE 2. THE FORCES EXERTED ON AN OBJECT IMMERSED IN A FLUID

fIt is named after Archimedes of Syracuse, who first discovered this law. According to Archimedes' principle, "Any object, wholly or partly immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.". Archimedes' principle does not consider the surface tension (capillarity) acting on the body.

The weight of the displaced fluid is directly proportional to the volume of the displaced fluid (if the surrounding fluid is of uniform density). Thus, among completely submerged objects with equal masses, objects with greater volume have greater buoyancy.

Suppose a rock's weight is measured as 10 newtons when suspended by a string in a vacuum. Suppose that when the rock is lowered by the string into water, it displaces water of weight 3 newtons. The force it then exerts on the string from which it hangs would be 10 newtons minus the 3 newtons of buoyant force: $10 - 3 = 7$ newtons. Buoyancy reduces the apparent weight of objects that have sunk completely to the sea floor. It is generally easier to lift an object up through the water than it is to pull it out of the water.

An object dropping in a liquid is floating or sinking following these conditions:

I) When Buoyancy (B) is greater than the weight (W) of the object, the object is floating on the surface of the liquid: **B > W**

II) When Buoyancy (B) is equal with the weight (W) of the object, the object is floating inside the liquid: **B = W**

III) When Buoyancy (B) is less than the weight (W) of the object, the object is resting on the bottom of the liquid: **B < W**

It is pointed out that, the buoyancy in case I concern the part of the body which is immersed in the water, while in cases II and III concerns the whole body.

4. PRIOR STUDENT KNOWLEDGE

The module aims at 10-11 years old, and more specifically at 5th grade students in primary school. Although the concepts required to attend this module are elementary (shape, mass, volume), the module requires some previous knowledge. More specifically:

- Students should own some primitive concepts of mass, volume, shape.
- Furthermore, they should be able to categorize objects taking into account one of the above characteristics. For example, they should be able to categorize objects of different weight, from the heavier to the lighter one.
- They should also be able distinguish possible factors affecting floating/sinking phenomena.
- In addition, students should be able to give explanations (not necessarily scientific) about floating/sinking phenomena, recalling their own experiences and taking into account their own ideas about these phenomena.
- They should be able to use several measuring tools, such as the balance, in order to collect data.
- Students should be able to understand the concept of concrete and the concept of composite objects.

5. AIMS OF THE MODULE

The module consists of five units. In Annex 1, we present the specific intended learning outcomes for each Unit. The aims of the module have 4 basic orientations in the context of materials science:

Scientific Conceptions and Phenomena

- Students should develop a semi-quantitative notion of the concept of density (crowdedness model) as a property of materials, in order to negotiate the property of density as a criterion for F/S of compact and compound objects.
- They should be able to understand that the density of a compound object lies between the densities of the materials that comprise this certain object.
- They should understand the factors affecting (material of the object and kind of the liquid) or non affecting (size of the object or the vessel) the F/S phenomena.

Fundamental Abilities of Inquiry

- Students should develop general abilities such as systematic observation, identifying and controlling variables, design and execute experiments, interpret data, use evidence for their explanations, gather and display data, construct conceptual models based on the experimental data and use them in describing and interpreting F/S phenomena.
- They should also be able to differentiate descriptions from explanations. Moreover students should be able to draw a conclusion taking into account evidence instead of expressing their own beliefs.
- Students should change their recreational view about models to more scientific one. Moreover they should acquire aspects of the nature and role of models.

Awareness of the science and technological aspects

- Students would be introduced to the fact that people can construct new materials with predetermined properties.
- They should approach the idea that behind the complicated technological objects, scientific laws and concepts are ‘hidden’.
- They should be able to recognise that the solution

of a technological problem needs a number of social, economical, and cultural factors besides the scientific ones.

- They should be able to evaluate and improve a solution in a technological problem, as well as to propose alternative solutions about that.

Interest and Motivation

- Students' interest and motivation about Science should be increased.
- Students should develop positive attitudes towards Science and Technology as well as to the respective careers.

6. PEDAGOGICAL APPROACH AND CONTEXT

6.1. INQUIRY LEARNING: CONTROL OF VARIABLES STRATEGY

The fundamental abilities necessary to do scientific inquiry at the grades 5-8 have been detailed in the National Research Council's Standards book (2000) and they are presented at the table 1. In this module we focus on the ability to design and interpret experiments in F/S phenomena so that conclusions can be reached regarding the role of a variable in the related phenomena.

The control of variables strategy, a specific scientific inquiry approach is used to characterize whether or not a variable influences the behaviour of a system (Boudreaux, 2008).

We teach our students the **Control of Variables Strategy** as a process which includes four steps:

- We predict which variables possibly affect F/S;
- 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;

- We test if this variable affects the phenomenon or not.
- We draw a conclusion.

Representative example of Control of Variables Strategy implementation: (See Part B, Unit 2, Episode 1, Activity 1)

FUNDAMENTAL ABILITIES NECESSARY TO DO SCIENTIFIC INQUIRY - GRADES 5-8
Identify questions that can be answered through scientific investigations
Design and conduct a scientific investigation
Use appropriate tools, and techniques to gather, analyze, and interpret data
Develop descriptions, explanations, predictions, and models using evidence
Think critically and logically to make the relationships between evidence and explanations
Recognize and analyze alternative explanations and predictions
Communicate scientific procedures and explanations
Use mathematics in all aspects of scientific inquiry

TABLE 1: USA'S NATIONAL RESEARCH COUNCIL'S STANDARDS FOR SCIENTIFIC INQUIRY

6.2. SCAFFOLDING INQUIRY LEARNING

Inquiry learning encompasses a wide range of types which varies along a continuum from open inquiry in which the degree of students' control is high e.g. they organize themselves, identify and pose questions, develop hypothetical explanations to more structured inquiry, in which teachers determine the questions and specific procedures of the investigation (Grawford, 2007; Herr, 2008).

Eight levels and types of scientific inquiry:
Discovery Learning, Interactive Demonstrations, Inquiry Lessons, Guided Inquiry Labs, Bounded Inquiry Labs, Free Inquiry Labs, Pure Hypothetical Inquiry, Applied Hypothetical Inquiry.
Source: Hanauer, D., Hatfull, G., Jacobs-Sera, D. (2009). Active Assessment. Assessing Scientific Inquiry. Springer, USA

This module concerns the case where students have limited experience of inquiry activities and as a consequence, we consider that they need guidance in undertaking inquiry. Indeed, Krajcik (2001) mentioned, *"Trying to rush the inquiry process is like teaching someone to swim by throwing him into the deep end of the pool."* (p. 92). In line with this consideration, we approach the notion of '**scaffolding**' whereby a student is guided by his/her teacher to undertake an experiment (or to solve a problem) in a gradually reduced support, as the student become able to complete it (Taber, 2009).

Scaffolding Inquiry Learning is implemented in four levels (see figure 3). The **first level** of 'guided inquiry' consists of a teacher-controlled activity through which students are directed to test a variable, following a specific method (the Control of Variables Strategy). The **second level** of 'guided inquiry' consists of a teacher-directed student inquiry in which students carry out an experiment in order to test another variable, following the same method. The **third level** of 'open inquiry' consists of a student inquiry experiment in order to test a variable that is posed by the teacher. Students are expected to design and conduct the experiment. Last, the fourth level of 'open inquiry' involves students to design inquiry experiments in order to test two variables that are posed by the teacher.

Representative examples of the Scaffolding Inquiry Learning implementation: (See Part B, Unit 1, Episode 2, Activity 3 and Unit 2).

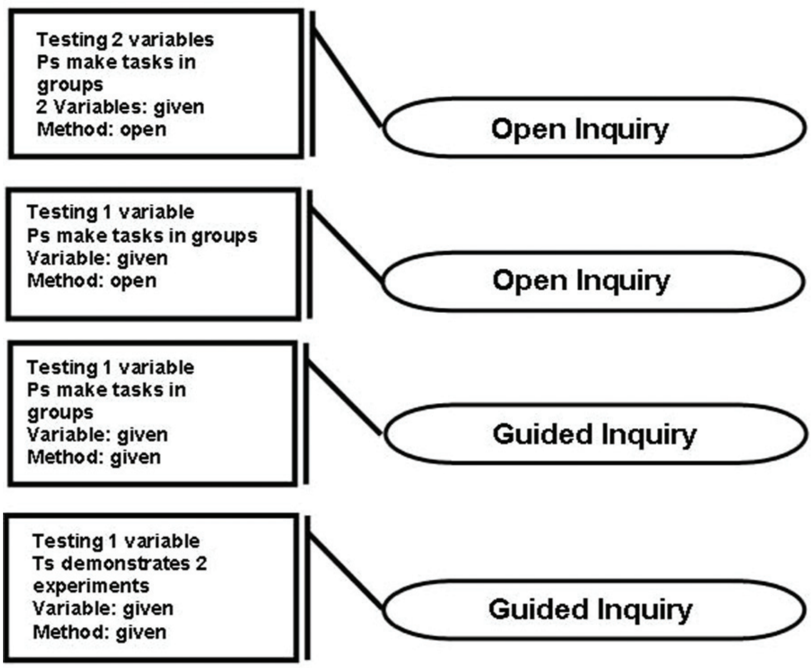


FIGURE 3: THE SCAFFOLDING INQUIRY DIAGRAM FOR APPROACHING SCIENTIFIC CONTENT

6.3. MODELS AND MODELLING

A model is the representation of a target which, in general, can be an object, a concept, a process or a phenomenon (Van Driel and Verloop, 1999). Its aim can be the description, the explanation or the prediction of a target. Gilbert et al. (2000) suggested a classification of the ontological status (the inherent status) of models: **Mental, expressed, consensus, scientific, historical, curricular, teaching models.**

Mental models are individual human constructs initially exist in the mind of a person, independently of whether this person is thinking alone or within a group. **Expressed models** are the mental models that are placed by an individual into the public domain through any form of expression (e.g., speech, writing).

Consensus models are the expressed models that are discussed and accepted in a specific community.

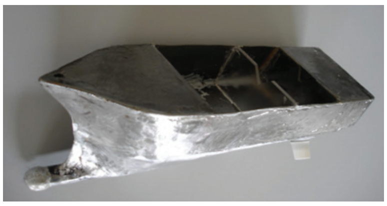
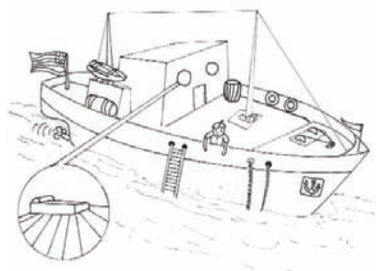
Scientific models are the expressed models that gained acceptance by a community of scientists following formal experimental testing, as manifest by its publication in a refereed journal.

Historical models are the consensus models developed in a specific context, namely a system of specific philosophical, scientific, technological, and social beliefs.

Curricular models are the usually simplified versions of scientific or historical models which are included in a formal curriculum.

Teaching models, may be defined as those models specially developed to help students understand consensus models and to support the evolution of mental models in specific scientific areas.

The mode of representation of a model varies and could be: concrete, verbal, visual, mathematical, gestural. In table 2 we present the models, concerning floating and sinking phenomena, which the teacher and the students negotiate during the implementation. The first four models of table 2 are teaching models which means that they aim to help students

UNIT	MODEL	AIM OF THE MODEL	MODE OF REPRESEN-TATION OF THE MODEL	ONTOLOGI-CAL STATUS (THE INHER-ENT NATURE OF MODELS)	TARGET OF THE MODEL (OBJECT, CONCEPT, PROCESS, PHENOMENON)
1, 4,5	 IRON MODEL OF A SHIP	Description	Material or concrete	qualitative, teaching model	A ship (object)
1	 SKETCH OF A SHIP	Description	Visual - Static	qualitative, teaching model	A ship (object)

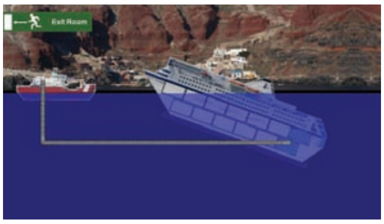
UNIT	MODEL	AIM OF THE MODEL	MODE OF REPRESEN-TATION OF THE MODEL	ONTOLOGI-CAL STATUS (THE INHER-ENT NATURE OF MODELS)	TARGET OF THE MODEL (OBJECT, CONCEPT, PROCESS, PHENOMENON)
4	 CROWDEDNESS MODEL	Description	Visual - Static	semi quantitative, teaching model	The concept of density (concept)
5	 SIMULATION OF SEA DIAMOND	Description	Visual - Dynamic	qualitative, teaching model	Floating and sinking of Sea Diamond cruise ship (phenomenon)
4	When density of an object (compact or compound) is more than density of a liquid the object sinks. When density of an object (compact or compound) is less than density of a liquid the object floats.	Causal model, Explanation and Prediction	Verbal – Law	Semi quantitative, curricular model	Floating and sinking phenomenon (phenomenon)

TABLE 2: INDICATIVE MODELS, CONCERNING FLOATING / SINKING, THAT TEACHER AND STUDENTS NEGOTIATE DURING THE IMPLEMENTATION

understand scientific models and enhance their conceptual models about floating sinking phenomena. The teaching models that are included in our module are expressed models in the sense that they are not mental models in students' minds. The fifth model in table 2 is a causal model which is a conceptual curricular model concerning the explanation and prediction of floating sinking phenomena. Furthermore, all the models are qualitative (Boulter and Buckley, 2000) except from the "crowdedness" model, and consequently the causal model for predicting f/s phenomena, which are semi –quantitative.

Acts of modelling, are the following: (i) **model learning**, namely, students learn existing models; (ii) **model use** for experimentation and prediction, namely, the 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 (Justi & Gilbert, 2002). In our module we focus on cases of modelling, corresponding to the above two first acts: **model learning** and **model use**. Specifically, we adopted the 'crowdedness visual model' (see table 2) in order to approach the concept of density (model learning, 3rd and 4th units). Furthermore, we asked students to use this model to predict and interpret f/s phenomena. For example, based on this model, they 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).

Although the focus in our module is on cases of model using, the main aim of the above acts of modelling is that students' causal reasoning transit from causal linear reasoning (e.g. the object floats because of its weight) to causal relational reasoning (e.g. an object floats when its density is less than the liquids density). This causal relational reasoning is expressed with the last model in table 2 which is a causal model and aims in explanation and prediction of the phenomenon of floating and sinking. This transition in students' reasoning is the result of the evolution of students' mental models having as a consequence the production of enhanced conceptual models, which should have the requirements of scientific models: (a) representing defined aspects of the phenomenon, being possible to be refined or falsified; (b) providing a mechanistic interpretation of the underpinnings of (that aspect of) the phenomenon; (c) being useful to formulate predictions which can be put to the experimental test (Constantinou, 2007). In this sense, conceptual **models' revision** and **construction**, namely the third and the fourth act of modelling, is the second important focus in this module which though is an implicit one, in the sense that we do not initiate any discussion about these aspects of modelling. We assume that this could be possible and more appropriate in a class that has more experience on modelling tasks, especially in cases that students build their own expressed models of phenomena that are not conceptually demanding as floating sinking phenomena and the concept of density.

Nature and role of models are considered as really important epistemological aspect of nature of science which can enhance students' conceptual evolution (Schwarz and White, 2005). Furthermore, model-based reasoning can be thought of as a continuum in which teachers begin with student's basic representational capacities and try to end up near the practices of scientists. In the middle is an intermediate form of representation and modelling (Petrosino, 2003). According to the above position, in the 1st unit of our module a discussion about the nature of models takes place, with the aid of two different (physical, sketch) models of a ship. In the 2nd unit the students implement real and simulated experiments in order to identify and control possible factors that affect F/S. In the 3rd unit the students are introduced to a visual representation of density (figure 4). Using this representation in relevant simulated experiments the students are expected to infer more abstract causal relationships like the predictive rule about F/S. We follow a **gradual approach** of the nature and the role of models moving from physical models like an iron-made ship representation (1st unit), to symbolic models like the visual model of density and finally to relational models concerning the rules of F/S (3rd unit).

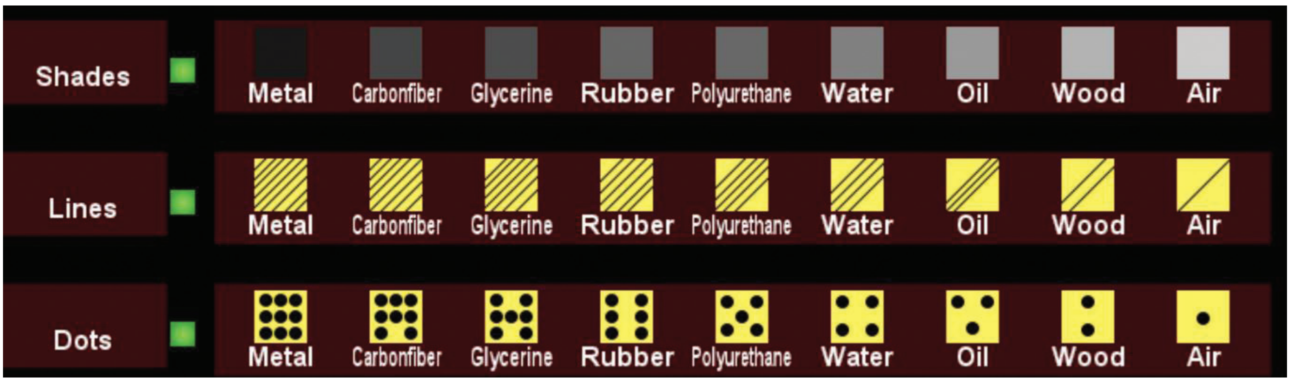


FIGURE 4: A SCREENSHOT FROM SOFTWARE DEPICTING THE VISUAL MODEL REPRESENTING DENSITY

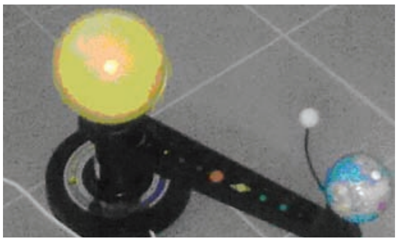
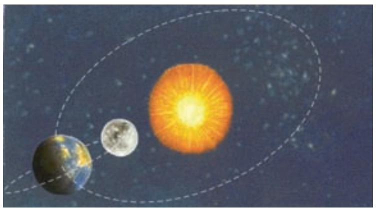
UNIT	MODEL	AIM OF THE MODEL	MODE OF REPRESEN-TATION OF THE MODEL	ONTOLOGI-CAL STATUS (THE INHER-ENT NATURE OF MODELS)	TARGET OF THE MODEL (OBJECT, CONCEPT, PROCESS, PHENOMENON)
4	 HELIOCENTRIC MODEL	Causal model, Explanation and Prediction	material or concrete	Expressed, qualitative, curricular, teaching model	Day and night phenomenon
4	 SKETCH OF HELIOCENTRIC MODEL	Description	Visual - Static	Expressed, qualitative, curricular, teaching model	Day and night phenomenon

TABLE 3: INDICATIVE MODELS THAT TEACHER AND STUDENTS NEGOTIATE DURING THE IMPLEMENTATION IN ORDER TO ENHANCE THEIR UNDERSTANDING OF ASPECTS OF NATURE AND ROLE OF MODELS

This transition is assisted by the negotiation of the students' causal (linear) models concerning the factors (e.g. the weight of the object) affecting F/S (2nd unit) so as to promote the passing from a simple linear causality to an interactive relational causality (Perkins & Grotzer, 2005). Finally in the 4th unit, through a discussion, with the aid of two different kinds of the heliocentric model (see table 3) and with the variety of the students' visual representations of density, we expect on the one hand that the students will generalize the concept of model in another context, and on the other hand they will acquire a more integrated view about the nature and the role of models. More specifically, we expect them 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 table 3).

STUDENTS IDEAS ABOUT MODELS	STUDENTS IDEAS ABOUT MODELS
Models can only exist in the concrete and material mode	Models may exist in a range of modes. Especially scientific models are more often in an abstract than concrete mode
Models are copies of a target	Models are representations of a target and not its replica
Models serve as exemplars	Models serve as tools to explain, interpret and predict a phenomenon
A target can be represented by only one model	A target can be represented by more than one models
Models purpose is only recreation and instruction	Scientific models purpose can be description but most often is explanation and prediction of a phenomenon

TABLE 4: DIFFERENCES BETWEEN STUDENTS' IDEAS ABOUT MODELS AND THE BASIC ASPECTS OF NATURE/ROLE OF MODELS IN SCIENCE EDUCATION

According to Gilbert (1991, p. 77) students have a relatively narrow and stereotypical view of models as three dimensional concrete objects constructed for recreation or instruction. It seems clear that if science is going to be defined as a process of model building, then priority must be given to expanding the conceptualization of models that most students seem to hold. By following the above teaching approach concerning models and modelling, we hypothesize that students will improve their understanding about basic aspects of the nature/role of models (see table 4).

Contextualization in everyday life: scientific and technological knowledge

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 like density (Tao & Gunstone, 1999; Yeo et al., 1999; Krajic, 2001). The scientific as well as the technological aspect of material properties are concurrently studied in this module.

"Richard White (1998) argues that when learning is contextualized it forms a memorable experience that gives access to the ideas. When learning is presented in context it becomes both an anchor for helping students develop their knowledge and an opportunity for students to apply what they know and make connections to new situations."
(Krajic, 2001; p. 13).

On the one hand density is introduced as a property of materials – an 'identity' of materials – using the crowdedness model. Students, based on this introduction, are expected to understand that density depends on the kind of material, as well as to be able to predict / interpret F/S phenomena by comparing the densities between materials. Furthermore we train them in the application of scientific inquiry methods, namely, we train them in control of variables strategy, and in learning scientific models.

On the other hand, students are asked to "find" the hidden property density behind the complicated technological world e.g. behind a sunken ship or a sunken statue. We also help them to become *"creative problem solvers"*, to evaluate the existing technology and to be able to change it, to become well-informed product users (see glycerine) and to find alternative technological solutions taking into account factors as aesthetics, environmental issues, and ergonomics, (see figure 5).

Representative examples of the Technology Learning implementation: (See Part B, Unit 5, Episode 3 and 4)

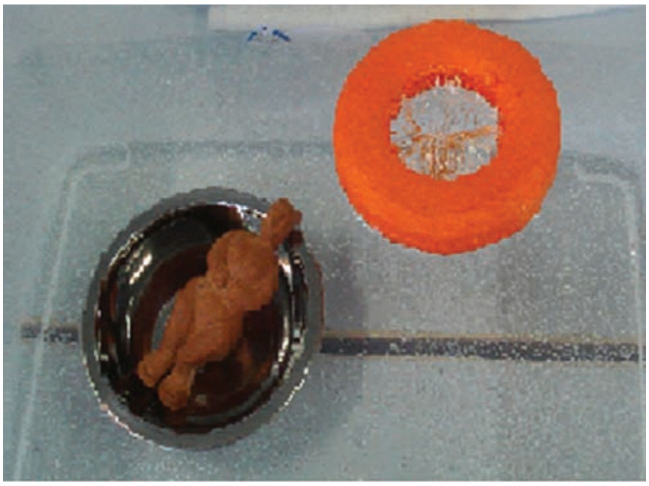


FIGURE 5: THE SALVAGE OF A SUNKEN STATUE: WE ASKED STUDENTS TO TAKE INTO ACCOUNT THE COST OF THE SALVAGE AS WELL THE STATUE'S PROTECTION.

7. RELEVANT ICT TOOLS

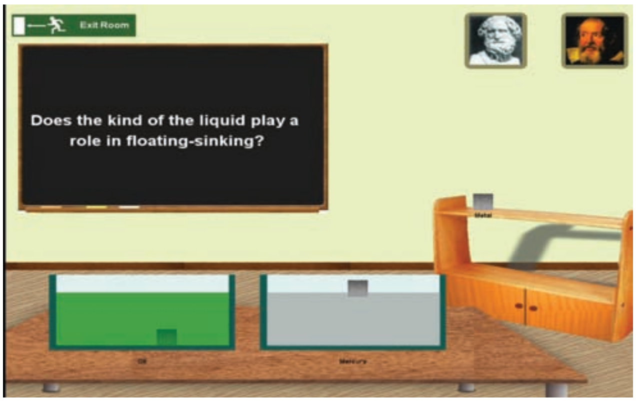
While studying the existing proposals of educational software which incorporate to a bigger or lesser degree those concepts of interest to us, we ascertained the insufficiency of satisfactory propositions mostly because of their orientation to mathematical encounters of the issue in question. Therefore, it was our conscious choice to develop some specially engineered software from scratch, which would follow closely the concepts we want to teach. The criteria set from the beginning, regarding the features of our software were:

- Playful character with profound interactive elements.
- Semi-open approach which allows experimenting in a controlled environment.
- Separation in units ("rooms"), which will follow the development of teaching.
- Realistic environment to represent liquids and solids, with no excessive 3D displays to disorientate.
- Easy to install and simple demands of the final software.
- Easy to translate the interface in other languages.

Ultimately, the software ended up to a single program for Microsoft Windows, making use of the Game Maker software. (http://www.yoyogames.com/gamemaker).

The software contents in its current version are the following:

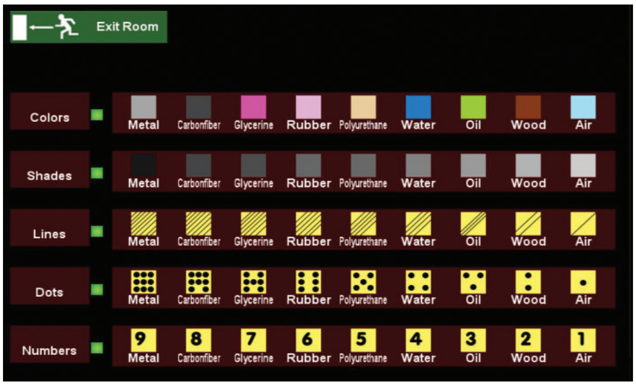
Four units ("rooms") where pupils are enabled to check the parameters that potentially influence floating-sinking.



Two units ("rooms"), where pupils are enabled to compare the weight of various materials (liquids, solids) aiming to their classification.

A virtual website that we have constructed in order to provide students the opportunity to gather information about various materials: carbon fibber, glycerine, latex and PVC.

A unit ("room") which includes various models representing the concept of density.



Two units ("rooms") where pupils are enabled to experiment with floating-sinking phenomena and get familiar with the crowdedness model, using it in predicting floating and sinking of several objects.

A unit ("room") where students can experiment in a virtual environment the sinking and the salvage of "Sea Diamond" cruise ship.

During the development process, the following problem appeared: Game Maker does not include any sort of internal hydrodynamic machine to represent F/S. That's why the Game Physics library was utilized, so that the most possible realistic depiction of the procedures involved would be achieved. Furthermore, the software runs on MS Windows XP and Vista.

8. COMMON STUDENT DIFFICULTIES

8.1. INTRODUCTION

Researchers have been becoming increasingly aware that, for a curriculum to be effective in bringing about conceptual change, it must first engage students' initial conceptions and then convince students of their concepts shortcomings. Thus, the module aims at making students aware of their conceptions, create dissatisfaction with their conceptions, and challenge them to revise their thinking in ways that resolve the anomalies, regarding this way the new conceptions as ultimately more plausible and fruitful than their old ones (Posner et al. 1982).

8.2. STUDENTS' MENTAL MODELS ABOUT SINKING AND FLOATING PHENOMENA AND ABOUT DENSITY

Researchers who studied pupils' conceptions of density (Hewson, 1986; Inhelder & Piaget, 1958; Rowell & Dawson, 1977; Smith, Carey, & Wiser, 1985) consider that for most pupils, density represents a relation between weight and volume and not between mass and volume. This consideration is due to the fact that the weight of a body can be perceived by lifting it (Driver, Squires, Rushworth, & Wood-Robinson, 1994) whereas mass is mostly a formal concept. In addition, the distinction between mass and weight is not achieved until at least the age of 14–15 years (Rowell & Dawson, 1977).

FURTHERMORE, according to the results of the clinical interviews conducted by Smith et al. (1992), the factors that came out to be relevant to floatation, according to children, are: **(a)** the weight of an object, **(b)** the size of an object, **(c)** whether or not it had holes or it was hollow, **(d)** how heavy it was for its size, **(e)** whether the material had air in it or it could absorb water, **(f)** how much water there was in the container, and **(g)** the kind of material it was made of.

NEVERTHELESS some children showed by both their pattern of judgments and justifications that they regarded density as an extensive quantity. According to Klopfer (1992) students have the following two difficulties in relation to density: a) Poor differentiation of mass, weight, volume and density, and b) Application of principles relevant to extensive quantities in reasoning about density, which is an intensive quantity.

IN ADDITION, relevant research (Kariotoglou 1991, Driver et al. 1994, Fassoulopoulos et al. 2003, Thassitis et al. 2004, Pnevmatikos et al. 2006), found out that 5-15 year old students formulate their estimation about the density of fluids as well as about the floating of solid objects in the water taking into account the following:

• The dimensions of vessels in which floating takes place. In these studies, students maintain that in narrow vessels, fluids are denser because they are compressed more and solid objects are pushed to the surface no matter their relative density to the water. • The depth of water.	• The weight of the bodies. In research, few students refer to the weight in relation to the size of bodies. Most of them provide different explanations for different objects. • The existence of hollows. • The shape of floating object.

According to Fassoulopoulos et al. (2003) research, referring to 12-15 year old pupils, two categories of children's alternative views about density emerged while they studied phenomena involving fluids at rest or in transition:

- extensive, when they consider that density is proportional to the quantity of the liquid and
- compressive, when they consider that density increases in narrow vessels.

In conclusion, density is a difficult notion for at least two reasons: Firstly, because it requires the use and comprehension of advanced mathematics like analogies, which, according to research, even 15 year old students have not yet consolidated. Secondly, because students have a conceptual framework different from the scientific one, in which the notion of density includes without distinction the accepted scientific notions of weight and density.

8.3. STUDENTS' LEARNING DIFFICULTIES CONCERNING CONTROL OF VARIABLES STRATEGY (CVS), MODELS AND MODELLING

According to relevant literature (NRC, 1996 and 2000; Boudreaux, Shaffer, Heron and McDermott, 2008) students have at least the following difficulties concerning control of variables strategy:

- Failure to distinguish between expectations and evidence.
- Reluctance to make inferences from data.
- Failure to control variables.
- Failure to realize that a variable must be changed to test for its influence.

Concurrently, students have a marginal knowledge about models and modelling as well as the nature and role of models. Students experience with general models (more commonly fit into the category of scale replica) is the starting point in their understanding of scientific models (which fit into many different forms, from scale replica to more abstract ones, and are used more analytically). Specifically, the most important difficulties that appear concerning models are that students (Gilbert, 1991; Treagust, 2002; Saari, 2003):

- Fail to distinguish between world as experienced and world of models.
- Assume models to have a recreational or instructional purpose.
- Assume models to be concrete and exact copies of their target. In other words they assume that the purpose of a model is that of copying.
- Assume that a model is an object.
- Assume that a model's fitness depends on who is making the model, but the model has to be as accurate as possible.
- Assume that a model can be changed if it contains errors or if its maker wishes to change it.

9. MONITORING STUDENT LEARNING

9.1. FORMATIVE AND SUMMATIVE ASSESSMENT

Assessment is a major concern in designing and running courses, and could be used both as a tool for measurement of student performance and as a tool for helping students to learn (Paulsen, 2003). The *Production Handbook for Open University Courses and Packs* (Paulsen, 2003) provides the following definitions:

Assessment is the general term used for measuring students' performance on a course against the aims and objectives of that course. Assessment may be formative or summative.

Formative Assessment is assessment as part of teaching: questions and assignments set to help the student learn effectively, but not used to determine the student's course results.

Summative Assessment is assessment to determine a student's overall level of performance on the course: questions and assignments, the grades or scores of which are used in determining the student's course result.

There is a potential conflict between formative and summative assessment as Rowntree (www-iet.open.ac.uk/pp/D.G.F.Rowntree/Assessment.html) describes in his article Designing an assessment system: *"...While formative assessment is usually for the student's benefit, summative assessment is often for the benefit of other people – e.g. other teachers or potential employers – who might use the information you provide to make decisions affecting the student's life-chances. Herein lies a potential conflict of roles for the teacher – between helper and informer – and a conflict between formative and summative assessment. Students who most need help may be reluctant to reveal their difficulties or to choose learning options that are more challenging, for fear of being adversely reported on...".*

9.2. INTENDED LEARNING OUTCOMES

In general, students' intended learning outcomes concerning each of the four contents that they negotiate in this module are the following:

a. Explanations for f/s phenomena: Students usually adopt a causal linear reasoning when they have to explain F/S phenomena. For example they assume that an object sinks because it is heavy. The intended learning outcome concerning F/S phenomena is that they manage to achieve causal relational reasoning, which means that they take into account the density of the object in relation to the density of the liquid.

b. Understanding of the concept of density: Students should a) assume that density depends on the material, and consequently is an intensive quantity; and b) differentiate between the concepts of weight and density.

c. Ability to design experiments using the control of variables strategy: Students should appreciate that the test of variables is effected through at least two measurements (in order that the comparison be possible) keeping all other variables constant, except for the variable under test. In addition, they should understand that observation in order to collect data is crucial in order to come to a conclusion.

d. Understanding features of the nature and role of models: students should assume 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 not only recreational (in terms of beauty, aesthetics and having fun) or instructional.

9.3. INSTRUMENTS FOR ASSESSMENT OF LEARNING OUTCOMES

In order to evaluate the effectiveness of the module we aim to compare students' cognitive final state with their cognitive initial state 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 (see 9.2.).

The instruments that the Local Working Group of Florina used to evaluate the effectiveness of the module, comprising the summative assessment of the module, are the following: **Pre- and post-questionnaires** for the 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** enable us to triangulate assertions generated from both quantitative and qualitative analysis.

9.4. MONITORING STUDENT ENGAGEMENT AND MOTIVATION

Active participation in the teaching and learning procedure is one of the basic prerequisites for learning. In our module, we try to promote this kind of students' enactment developing a scenario which is based on a real event, the Sea Diamond cruise ship wreck (April 2007). The scenario involves the students in the problem solving of the salvage of an iron model of a ship. Continuing, the students are driven to study the factors that influence objects' f/s. This demands the introduction of an object's property – concept, e.g. density.

It also seeks to develop students' incentives and interest in Science and Technology as such, as well as in future careers of students. In this sense contributes on the one hand the technical problem mentioned above and other exploratory learning environment we have created. In this, the students work on their own or in groups to design and implement experiments to draw conclusions and communicate their results. This authentic environment for investigation, which resembles that of scientists, always taking into account the age of the students, we assume that motivates pupils and enhances their interest in Science and Technology. This is because we believe that the use of models by scientists are not just a means to help their logical reasoning, but are a special kind of reasoning, with which students will get familiarized in order to understand and to feel it as their own (Nersessian, 2008). As highlighted by Hatano & Inagaki (1991) the group discussion and interaction during the time of the course have as a key feature that students are involved in such activities in order to understand the concepts forced by their social motivation as well as cognitive or scientific incentives. Creating, then, appropriate circumstances as an authentic environment where students investigate, work and interact in groups, expectations to activate students' interests and motivations towards Science and Technology, are increasing.

To check the above hypotheses, we have adapted two questionnaires, the first one, «Academic Motivation for

Learning Science (AMLS)», to measure students' motivation, and the second one, «Evaluation of Science Inquiry Activities - Questionnaire (ESIAQ)», for evaluating the activities carried out by the students compared with those traditionally implemented in the Greek School. The original questionnaire was developed by the Finnish research team. In particular, AMLS is based on "Self-Regulation Questionnaire" (SRQ-A), which was developed by Ryan and Connel (1989) and" Academic Motivation Scale" (AMS) created by Vallerarand, Pelletier, Blais, Briere, Senecal, and Vallieres (1992), both based on the Self-Determination Theory (Deci & Ryan, 2004). The questionnaire measures the motivation of children with regard to different types of motivation described by the theory of self-determination: lack of motivation (amotivation), external regulated motivation (external regulation) introjected regulation of motivation (introjected regulation), recognizable setting (identified regulation) and internal motivation. Students replied using a 7-grade Likert scale where 1 indicates total disagreement and 7 total agreement. According to the students' answers concerning their motivation and interest for Science 5 students were selected as representatives of each type of motivation. The selection was made using the K-Cluster Analysis. Students which were selected were the ones who were closer to the centers of clusters representing each type of mobilization. These students were interviewed after the intervention.

The "Evaluation of Science Inquiry Activities – Questionnaire" questionnaire (ESIAQ) was based on "Intrinsic Motivation Invertory" (IMI), a tool that measures various aspects related to motivation and includes 43 proposals that were aiming to measure the subjective experience of participants with regard to an activity (Deci, Eghari, Patrick, & Leone, 1994). In this case, we made a measurement to measure participants' subjective experience on such, usual science course, activities, just before the intervention, and one measurement after the intervention, which involved the measurement of subjective experience of participants in the module which was developed in the frame of the project. The questionnaire contains 43 proposals referred to the seven subscales: interest / enjoyment, (7 items), perceived competence, effort, value/usefulness, felt pressure and tension, perceived choice and social relatedness.

10. OTHER USEFUL INFORMATION – LIST OF RELEVANT ARTICLES, LINKS TO WEB SITES

10.1. RELEVANT ARTICLES OF RESEARCH ON STUDENTS' AND/OR TEACHERS' CONCEPTIONS

Our selected bibliography, in chapter 11, includes students' and/or teachers' conceptions concerning:

- The concept of density (15, 17, 33, 42)
- Explanations about floating sinking phenomena (17, 25, 27, 29, 38, 42)
- Physical properties of matter (18)
- Models and modelling (2, 3, 10, 11, 16, 22, 24, 26, 31, 39, 41)
- Control of Variables Strategy (1, 4, 35)

The number in brackets corresponds to the respective references, in chapter 11.

10.2. WEB SITES OF TEACHING PROPOSALS AND PROJECTS FOR TEACHING MATERIALS SCIENCE

MATERIALS SCIENCE AND TECHNOLOGY TEACHERS' WORKSHOP (MAST)
http://matse1.mse.uiuc.edu/

MATTER PROJECT (Computer Based Learning Resources in Materials Science done by Materials Science Researchers in UK)
http://www.matter.org.uk/default.htm
For schools: http://www.matter.org.uk/schools.htm

TEACHINGIDEAS, (section MATERIALS AND THEIR PROPERTIES (list of basically hands-on activities for primary school teaching)
http://www.teachingideas.co.uk/science/contents2materials.htm

SCIENCEBUDDIES, section PROJECT IDEAS ABOUT MATERIALS SCIENCE (different ideas for school research projects with different levels of complexity)
http://www.sciencebuddies.org/mentoring/project_ideas/home_MatlSci.shtml

PRINCETON CENTRE OF COMPLEX MATERIAL, (outreach programmes for teachers and undergraduates)
http://www.princeton.edu/~pccm/outreach/index.htm

COMPOMENT FAILURE MUSEUM, Open University. (includes examples of problems of some materials as the starting point for analysing their properties)
http://technology.open.ac.uk/materials/mem/

MATTER PROJECT, lead by University of Liverpool (Computer Based Learning Resources in Materials Science done by Materials Science Researchers in UK)
http://www.matter.org.uk/default.htm
For universities: http://www.matter.org.uk/universities.htm

MATERIALS INTERACTIVE WEBSITE from the National Physical Laboratory (a set of applets in materials Science)
http://materials.npl.co.uk/netshare/guest/

MATWEB (database of properties of materials)
http://www.matweb.com/index.asp?ckck=1

UK CENTER FOR MATERIALS EDUCATION (includes a database of educational resources about Materials Science teaching)
http://www.materials.ac.uk/index.asp

TOP 50 moments in the history of materials (by the TMS: The Minerals, Metals and Materials Society)
http://www.materialmoments.org/vote.html

10.3. WEBSITES CONCERNING TEACHING APPROACHES ABOUT FLOATING AND SINKING

School of Education, Resources - Science and Environmental Education, Floating and sinking
http://www.deakin.edu.au/arts-ed/education/sci-enviro-ed/early-years/floating.php

Desinging effective projects: Project-Based Units to Engage Students
Float that boat!
http://www97.intel.com/en/ProjectDesign/UnitPlanIndex/FloatThatBoat/

planet science news
Activity: Getting Sorted
http://www.planet-science.com/about_sy/news/ps_151-175/ps_issue159.html

Teachers pay teachers, An open marketplace for educators Science sinking and floating Banner Sign Poster Chart
http://www.teacherspayteachers.com/Product/Science-Sinking-And-Floating-Banner-Sign-Poster-Chart

Pollen, A community approach to a sustainable growth of science education in Europe
http://www.pollen-europa.net/telecharger.php?rep=WQo49nYlhJ3dNUlpqszx7A%3D%3D&nom=X07mOTneHThynws8TjtevskNaI3osL8t

Microdensity of plastics
http://services.juniata.edu/ScienceInMotion/chem/standardslabs/15%20-Microdensities%20of%20Plastic.doc

10.4. WEBSITES CONCERNING MATERIALS' DENSITIES

Density of materials
http://www.simetric.co.uk/si_materials.htm

Plastics densities
http://materials.globalspec.com/Industrial-Directory/plastic_density

Plastics densities
http://dwb4.unl.edu/chemistry/smallscale/SS069c.html

Plastics the Second Time Around
http://matse1.mse.uiuc.edu/polymers/h.html

Plastics Density range
http://www.plasticsrecycling.org/technical_resources/design_for_recyclability_guidelines/density_range.asp

the Educator's reference desk (fun with density)
http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Physical_Sciences/PHY0204.html

Science museum of Minnesota (density)
http://www.sci.mus.mn.us/sln/tf/d/density/density.html

Science museum of Minnesota (liquidlayers)
http://www.sci.mus.mn.us/sln/tf/l/liquidlayers/liquidlayers.html

Jefferson Lab (Hands-on activities, design and engineering)
http://education.jlab.org/indexpages/teachers.php

volume-density activities
Descartes' Diver "Snack",
Bubble Suspension "Snack",
Condiment Diver "Snack",
Glitter Globe Activity,
Salt Volcano Activity.

10.5. APPLETS & VIDEOS CONCERNING FLOATING SINKING AND DENSITY

Digger and the gang
http://www.bbc.co.uk/schools/digger/5_7entry/8continue.shtml

Buoyancy game show
http://www.surfnetkids.com/quiz/buoyancy/
Buoyancy mix and match
http://www.surfnetkids.com/games/buoyancy-mm.htm

Sink or float? Word search
http://www.surfnetkids.com/games/buoyancy-ws.htm

Quizzes
http://www.abc.net.au/science/experimentals/quizzes/two/

Buoyancy
http://www.spin.gr/static/sections/applets/buoyforce/index.html

Will this object sink or float? Choose below
http://www.qqwkids.com/view.asp?id=2290

Sink of float? An interactive game for 3rd graders
http://www.authorstream.com/Presentation/tutray-142180-sink-or-float-science-education-ppt-powerpoint/

Activity Making and Sinking a Foil Boat - Cullen's abc's
http://www.youtube.com/watch?v=X4C_clFVX3c

11. REFERENCES

1. Boudreaux, A. Shaffer, P.S., Heron, R.L., McDermott, L.C. (2008). Student Understanding of control of variables: Deciding whether or not a variable influences the behaviour of a system, American journal of Physics, 76 (2), 163-170
2. Boulter, C.J., Buckley B.C., “Constructing a Typology of Models for Science Education” In Developing Models in Science Education edited by Gilbert, J.K., Boulter, C.J. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2000.
3. Constantinou, C. (2007). Modelling in Science and Education. Proceedings of the Sixth International ESERA Conference. Malmö, Sweden.
4. Crawford, B. A. (2007). Learning to Teach Science as Inquiry in the Rough and Tumble of Practice. Journal of Research in Science Teaching, 44(4), 613-642.
5. Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating Internalization: The Self-Determination Theory Perspective. Journal of Personality, 62(1), 119-142.
6. Deci, E.L., & Ryan, R.M. (2000). The “what” and “why” of goal pursuits: Human needs and self-determination of behaviour. Psychological Inquiry, 11, 227-268.
7. Deci, E.L., & Ryan, R.M. (2004). Handbook of Self-determination Research. Rochester, NY: The University of Rochester Press.
8. Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). Making sense of secondary science (p. 78). London: Routledge.
9. Fassoulopoulos, G., Kariotoglou, P., Koumaras, P. (2003). Consistent and Inconsistent Pupil’s Reasoning about Intensive Quantities, The Case of Density and Pressure, Research in Science Education, 33: 71-87

10. Gilbert, S. W. (1991). Model building and a definition of science. Journal of Research in Science Teaching, 28(1), 73–79.

11. Gilbert, J.K., Boulter, C. and Elmer, R. (2000). 'Positioning models in science education and in design and technology education. In J.K. Gilbert and C. Boulter (eds), Developing Models in Science education. Dordrecht: Kluwer, 2000, pp. 3-17

12. Hanauer, D., Hatfull, G., Jacobs-Sera, D. (2009). Active Assessment. Assessing Scientific Inquiry. Springer, USA, 14-15

13. Hatano, G. & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. In B. Resnick, J,M. Levine, & S.D. Teasley (eds.), Perspectives on socially shared cognition (pp. 331-348). Washington DC: American Psychological Association.

14. Herr, N. (2008). The Sourcebook for teaching science. Strategies, activities, and instructional resources. Published by Jossey-Bass, San Francisco, Unites States of America, 458-472.

15. Hewson, M. (1986). The Acquisition of Scientific Knowledge: Analysis and Representation of Student Conceptions Concerning Density, Science Education, 70(2) pp.159-170.

16. Justi, R. and Gilbert, J. K. (2002). Science teachers' knowledge about and attitudes towards the use of models and modelling in learning science. International Journal of Science Education, 24(12): 1273-1292

17. Kariotoglou, P. (1991). Issues of teaching and learning fluids mechanics in Greek Gymnasium. Unpublished doctoral thesis, Physics Department, Aristotle University of Thessaloniki, Greece (in Greek).

18. Klopfer, L., Champagne A. & Chaiklin, S. (1992). The Ubiquitous Quantities: Explorations that inform the design of instruction on the physical properties of matter, Science Education, 76, 597-614

19. Krajcik, J. (2001). Supporting Science Learning in Context: Project-Based Learning. In: Tinker, R. & Krajck, J. (eds), Portable Technologies: Science Learning in Context. Kluwer Academic/Plenum Publishers, ISBN 0-306-46643-0, New York, 7-28.

20. National Research Council. (1996). National Science Education Standards: Observe, interact, change, learn. Washington, DC: National Academy Press.

21. National Research Council. (2000). Inquiry and the National Science Education Standards: A guide for teaching and learning. Washington, DC: National Academy Press.

22. Nersessian, N. (2008). Mental modelling in conceptual change. In S. Vosniadou (ed.), International handbook of research on conceptual change, (pp. 391-416). New York: Routledge.

23. Paulsen M.F. (2003). Online Education - Learning Management Systems, nki Forlaget, http://www.nkiforlaget.no/aspx/prdinfo.aspx?plid=4235

24. Penner, D., Giles, N., Lehrer, R., Schauble, L. (1997). Building Functional Models: Designing an Elbow. Journal of Research in Science Teaching, 34(2), 125–143

25. Perkins, D., Grotzer, T. (2005). Dimensions of causal understanding: the role of complex causal models in students' understanding of science. Studies in Science Education, 41,117-166

26. Petrosino, A. (2003). Commentary: A framework for supporting learning and teaching about mathematical and scientific models. Contemporary Issues in Technology and Teacher Education, 3(3), 288-299.

27. Pnevmatikos, D., Kariotoglou, P. and Nikolopoulou E. (2006). Children's conceptions about floating and sinking: A microgenetic approach, presented in 5th European symposium Conceptual change: bridging the gap between mental models and situated cognition?, Stockholm, Sweden

28. Posner, G.J, Strike, K.A. Hewson, P.W & Gertzog, W.A. (1982) Accommodation of scientific conceptions: Towards a theory of conceptual change, Science Education, 66, pp. 211-217

29. Rowell, J., Dawson, C. (1977b). Teaching about Floating and Sinking: Further Studies Toward the Gap between Cognitive Psychology and Classroom Practice, Science Education, 61(4), 527-540.

30. Ryan, R.M., & Connell, J.P. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. Journal of Personality and Social Psychology, 57, 749-761.

31. Saari, H., Viiri, J. (2003). A research-based teaching sequence for teaching the concept of modelling to seventh-grade students, International Journal of Science Education, vol.25, no.11, 1333-1352

32. Schwarz, C., White, B. (2005). Metamodelling Knowledge: Developing Students' Understanding of Scientific Modelling, Cognition and Instruction, 23(2), 165-205

33. Smith, C., Carey, S. & Wiser, M. (1985). On differentiation: A case study of the development of the concepts of size weight and density. Cognition, 21, 177 – 237. Rowell, J., Dawson, C. (1977a). Teaching about Floating and Sinking: An Attempt to Link Cognitive Psychology with Classroom Practice, Science Education, 61(2), 245-253

34. Smith, C., Snir, J., Grosslight, L. (1992). Using Conceptual Models to Facilitate Conceptual Change: The Case of Weight-Density Differentiation, Cognition and Instruction, 9(3), 221-283

35. Sutman, F., Schmuckler, J. & Woodfield, J. (2008). The Science Quest. Using Inquiry/Discovery to Enhance Student Learning, Grades 7-12. Published by Jossey-Bass, USA, 89, 125.

36. Taber, K. (2009). Progressing Science Education. Constructing the Scientific Research Programma into the Contingent Nature of Learning. Springer,USA, 45, 310.

37. Tao, P., & Gunstone, R. (1999a). The process of conceptual change in force and motion during computer-supported physics instruction. Journal of Research in Science Teaching, 36(17), 859–882.

38. Thassitis, M., Fassoulopoulos, G. Kariotoglou, P. (2004). Study on the (in) consistency of students' views: Application on floating/sinking of bodies. In Tselfes, V., Kariotoglou P., Patsadakis, M. (eds.) Science, Teaching, Learning and Education, Vol. A. Proceedings of the 4th Panhellenic Conference for Science Education and New Technologies in Education, p. 399 - 455

39. Treagust, D., Chittleborough, G., Mamiala, T. (2002). Student's understanding of the role of scientific models in learning science. International Journal of Science Education, 24(4): 357-368

40. Vallerand, R.J., Pelletier, L.G., Blais, M.B., Brière, N.M., Senécal, C.B., & Vallières, E.F. (1992) The Academic Motivation Scale: Measure of Intrinsic, Extrinsic, And Motivation in Education. Educational and Psychological Measurements, 52, 1003 – 1017.

41. Van Driel, J.H., Verloop, N. (1999). Teachers' knowledge of models and modelling in science, International Journal of Science Education, 21, 1141-1153

42. Wikipedia http://en.wikipedia.org/wiki/Main_Page (last access 23/07/2009)

43. Yeo, S., Loss, R., Zadnik, M., & Treagust, D. (1999). Changing conceptions with an "intelligent tutor". In K. Martin, N. Stanley, & N. Davison (Eds.), Proceedings of the 8th Annual Teaching Learning Forum, Teaching in the Disciplines/ Learning in Context (pp. 474–483). The University of Western Australia. February. http://lsn.curtin.edu.au/tlf/tlf1999/yeo.html.

B: DESCRIPTION OF TEACHING AND LEARNING ACTIVITIES

B: DESCRIPTION OF TEACHING AND LEARNING ACTIVITIES

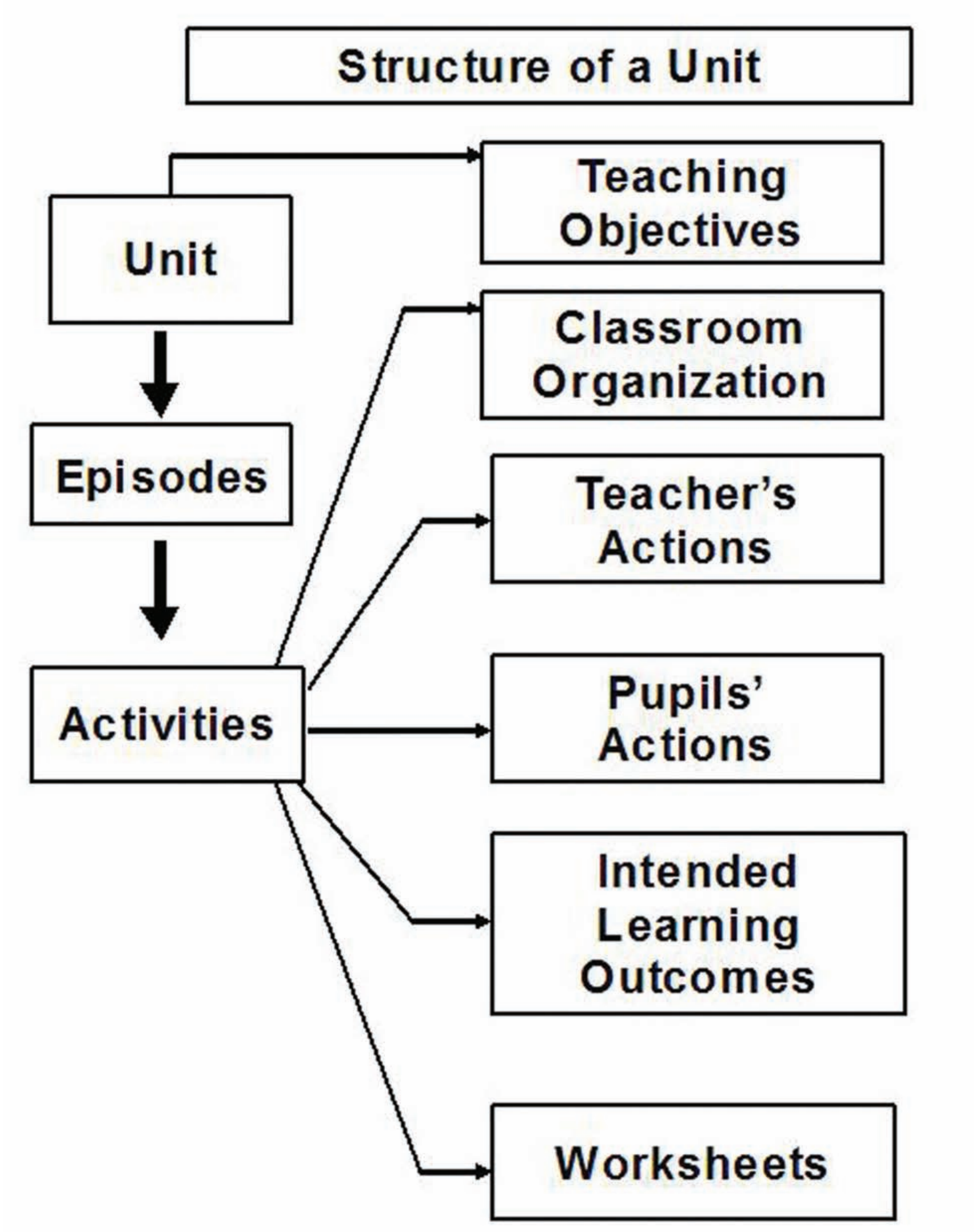


FIGURE 1: THE ABOVE FIGURE PRESENTS THE STRUCTURE OF EACH UNIT.

- At the beginning of each lesson, the teaching objectives are recorded. Each unit consists of a certain number of episodes.
- Each episode has individual features since it negotiates a specific area of the content, e.g. «Sinking & Floating» or acquisition of certain scientific skills, e.g. Distinction and Control of Variables.
- Each episode consists of a certain number of activities. Each one targets to specially intended learning outcomes. Only in the case where we aim at pupils' familiarization with the problem we study, there do not exist intended learning outcomes.
- Each activity includes classroom organization, e.g. pupils work in groups, teacher's actions, pupils' actions, intended learning outcomes, worksheets. Worksheets are given to pupils after the presentation of the whole unit.

UNIT 1: FLOATING – SINKING

Teaching Objectives

- Students are familiarized with the phenomena under study: Floating / Sinking
- Students are introduced in the experimental methodology (distinction and control of variables)

1st Episode: Sinking & Floating – Nature of models
Activity 1

Intended Learning Outcomes: -

Classroom Organization: The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
Questioning - Have you ever travelled by ship? - What objects can be found in a ship; - Which parts is a ship made of? - We will see on the computer some pictures of a Greek ship called Sea Diamond. Has anyone ever heard of her? - What happened with this ship last summer? Where did it happen?	- The students answer individually the questions
PART B	
- He/she asks pupils to work in groups at the PC.	- They observe (twice) the video of the ship Sea Diamond on the PC.
- He/she gives the «Worksheet 1.1».	- They fill in the "Worksheet 1.1".
- He /she asks the students to announce their written answers.	- The students announce their answers in groups.

WORKSHEET: 1.1

Activity 2

Intended Learning Outcomes:

(1) Pupils learn that a model is a representation of an object that helps us to describe the object.

(2) Pupils learn that a model is not a copy of the object.

Classroom Organization: Pupils work in groups

TEACHER'S ACTIONS	PUPILS' ACTIONS
- He/she gives pupils the "Worksheet 1.2".	- They observe the sketch. - They fill in the "Worksheet 1.2".
- The teacher asks pupils to announce their answers. - Why do we call the model "sketch? Because it is not exactly the same as the ship. It just helps us to observe the parts of the ship we want. It is a representation.	- The groups announce their answers.

WORKSHEET: 1.2

Activity 3

Intended Learning Outcomes:

Pupils learn that an object could be represented by more than one models.

Classroom Organization: Pupils work in groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
- He/she asks pupils to work in groups - - He/she gives pupils the "Worksheet 1.3" - The teacher asks pupils to announce their answers insisting on the discussion on the model. - He/she can conclude noting that we have 2 different models of the same technological object: a sketch and an object.	- They observe the small ship they have on their desk. They experiment to see whether it will float or not in the water - They fill in the "Worksheet 1.3" after discussing with their group. - The groups announce their answers to all pupils and some discussion takes place guided by the teacher.

WORKSHEET: 1.3

2nd Episode: Distinction and Control of Variables
Activity 1

Intended Learning Outcomes:
Pupils can distinguish the possible factors affecting floating/sinking.

Classroom Organization:
The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
Questioning - I hold a piece of iron. We say that this object is compact. What does this mean (the compact object)? - If I drop it in the water, will it sink or not? What do you think? - Why does it sink? - But please answer me this: What could I do to make it float? What could we change? - Let us watch it on the computer as well. Here is a piece of an iron cube which is already sunk. It does not contain water like the ship. What could I do to make it float? What could we change? .... (Discussion of the teacher with the pupils) - He/she writes on the blackboard the variables **(Form, Weight, Material, Liquid, Narrow/Wide vessel)** - He/she presents the variables at a poster	- The students answer individually the questions

WORKSHEET:-

Activity 2

Intended Learning Outcomes:
Pupils learn that the weight of a body does not affect its floating/sinking.

Classroom Organization:
The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
Questioning - How will I check if the weight of the object affects its sinking or not? - What will I have to decide regarding the remaining variables? - The teacher performs the experiment of the "Worksheet 1.4" as a demonstration experiment.	- They answer individually the questions - They fill in the "Worksheet 1.4" taking into account the findings of the demonstration experiment the teacher performed.

WORKSHEET: 1.4, SOFTWARE: ROOM "TESTING BODY WEIGHT"

Activity 3

Intended Learning Outcomes:
Pupils learn the procedure of control of a possible variable (weight)

Classroom Organization:
The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
Questioning - The teacher shows step by step, using a transparency, the experimental method they followed. - Please note that it is important that pupils revise by themselves the method. - If you saw that the big object floats and the small one sinks, would you draw the same conclusion?	- They answer individually the questions

WORKSHEET: -

UNIT 2: THE FACTORS AFFECTING FLOATING AND SINKING

Teaching Objectives

1. Pupils investigate the factors that possibly affect the phenomenon of sinking/floating of homogenous objects.
2. Pupils practice to the procedure of distinction and control of variables as well as to the procedure of drawing conclusions.

1st Episode: Distinction and control of variables for the phenomenon of f/s

Activity 1

Intended Learning Outcomes:
Pupils learn that the width of the vessel does not affect floating/sinking of bodies.

Classroom Organization: Group work – The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
Questioning - The teacher asks pupils to reflect on the methodology they followed in order to find out that weight does not affect the floating/sinking of a body. - The Power Point presentations comes first and then the poster.	- Pupils describe the steps of the methodology watching at the same time the p.p. transparencies.
PART B	
- He/she facilitates the work in groups – real experiment - The teacher collects the results..	- They work on the "Worksheet 2.1". They experiment, discuss and answer the questions. Phenomenon: Floating of wood. - They announce their answers.
PART C	
- Do the same experiment on the computer. - The teacher collects the results. **Questioning** - How will I check whether the width of the vessel affects or not the sinking of an object in a liquid filling the specific vessel? - What will I have to decide on all this factors? - Can I draw conclusions using only one vessel? How many vessels are necessary? - Right, the more vessels we have the surer we get. But which is the least number of vessels we should have? - Good. Do you think we could take a decision using only one vessel? - Indeed, when doing science we have to check several different cases so as to be sure. In this case however, we try only the case 2 so as to save time.	- They work on the "Worksheet 2.2". They experiment, discuss and answer the questions. Phenomenon: Floating of marble. - They announce their answers. - Pupils answer individually to the teacher's questions.

WORKSHEET: 2.1 – 2.2, SOFTWARE: ROOM "TESTING WIDTH OF CONTAINERS"

Activity 2

Intended Learning Outcomes:

1) Pupils learn that the kind of liquid does not affect floating and sinking.
2) Pupils learn to design an experiment to control a variable (kind of liquid)

Classroom Organization:

Group work – The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
- He/she facilitates the work in groups	- They work on the "Worksheet 2.3". They experiment, discuss and answer the questions
PART B	
Questioning - How will I check whether the kind of liquid affects or not the sinking of body inside it? How did the first group work? - Good. What about the 2nd ….. ? - What will I have to decide on the remaining factors? - Discussion with groups. Focus on the methodology.	- They announce the results.

WORKSHEET: 2.3, SOFTWARE: ROOM "TESTING LIQUIDS"

Activity 3

Intended Learning Outcomes:

1) Pupils are able to design experiments so as to check two factors at the same time, which possibly affect a phenomenon.
2) Pupils learn that the kind of material affects floating/sinking.
3) Pupils learn that the form of an object does not affect floating/sinking.

Classroom Organization:

Group work – The teacher discusses with all pupils

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
- He/she facilitates the work in groups	- They work on the "Worksheet 2.4". They experiment, discuss and answer the questions
PART B	
Questioning - How will I check whether the form of the object and the kind of material affects or not the sinking of body inside it? How did the first group work? What did the 2nd group? What different things did the other group? Do you want to add anything? - Good. What about the 2nd …? - What will I have to decide on the remaining factors?	- They announce the results.

WORKSHEET: 2.4, SOFTWARE: ROOM "TESTING BODY MATERIAL AND SHAPE"

Activity 4

Intended Learning Outcomes:
Pupils realise the differences between their initial and their final views and the reason that caused them.

Classroom Organization:
The teacher discusses with all pupils.

TEACHER'S ACTIONS	PUPILS' ACTIONS
Questioning - The teacher helps pupils to reflect on the progress of the research that took place in all experiment activities (investigation of possible factors / variable check) - What did we do to check if the width of the vessel affects the floating/sinking of a body? - Would it be possible to put wood or iron in one of the vessels? Why? - Would it be possible to put oil in one of the vessels and vinegar in the other? - Demonstration transparencies on the computer. - Which factors definitely affect floating/sinking and which ones do not?	- Pupils answer individually to the teacher's questions.

WORKSHEET: -

UNIT 3: INTRODUCTION OF DENSITY AS A CRITERION FOR FLOATING AND SINKING IN WATER

Teaching Objectives

1. Pupils are introduced to the notion of density by means of its visual model.
2. Pupils use the above mentioned notion of density as a criterion of approaching floating and sinking of bodies.
3. Pupils approach the nature of models and practice to modelling skills.

1st Episode: Necessity of a criterion of floating – sinking

Activity 1

Intended Learning Outcomes:

(1) Pupils get aware of the necessity of a criterion, of a property of materials towards the study of f/s of bodies.

(2) Pupils get aware that, except of the materials existing in nature, people can construct new materials with predetermined properties.

Classroom Organization:

The teacher discusses with all pupils and groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
- Let's see now, which materials float and which ones sink in the water? - Except for the water, tell me some liquids you know. What liquids do we use at home? - Tell me 2-3 solid materials you know. - Now it's my turn to tell you: glass, rubber, acrylic, PVC. Have you ever heard of them? As for liquids, I suggest the glycerine. - Go to the computer and try to find information on glycerine, the rubber and the PVC. - The teacher asks pupils to answer filling each frame with a few words.	- The pupils answer the teacher's questions. - The pupils fill in the "Worksheet 3.1". - The pupils work in groups to collect information on rubber and glycerine. - Discussion in the classroom. Pupils announce their answers.

WORKSHEET: 3.1, SOFTWARE: ROOM "INFORMATION ABOUT MATERIALS"

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART B	
- Here are some more materials. They are all in form of cylinder. Take them in your hands. This is of acrylic; this is of rubber… … - You just saw some new materials. Do you know which ones float and which ones sink? Is there any rule which can help us to predict which material sinks in which material? For example, does rubber sink in glycerine? Acrylic in glycerine? - Can you name the property that makes a material float or sink? - See now the experiment I am doing: can we predict whether acrylic sinks in syrup or in the dish detergent? - That means we can be sure? What will we do? Will we be trying each material separately? Sometimes it's difficult: you saw that acrylic was floating on syrup. We have to make up something for this. We seem to miss something.	- The pupils answer the teacher's questions.

WORKSHEET: 3.1, SOFTWARE: ROOM "INFORMATION ABOUT MATERIALS"

2nd Episode: Introduction of a visual representation of density
Activity 1

Intended Learning Outcomes:

- Pupils get aware that we can create representation models in order to represent a property of bodies.
- Pupils get aware that there is not a unique representation/model representing a specific property and that they may be more than one.

Classroom Organization:
Work in groups – The teacher discusses with all pupils and all groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
- The teacher encourages pupils to work on the computer in groups.	- The pupils fill in the first part of the "Worksheet 3.2". - They announce their results.

WORKSHEET: 3.2, SOFTWARE: ROOM "WEIGHING MATERIALS 1"

Activity 2

Intended Learning Outcomes:
Pupils get aware that their representations may differ so that they distinguish between a heavy and a light object of the same volume.

Classroom Organization:
Work in groups – The teacher discusses with all pupils and all groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
- The teacher encourages pupils to draw what they really imagine. They draw only with pencil. - How would you represent the cubes regarding their difference? That one can be heavier or lighter than the other. - How would you draw them? How do you imagine them? - What could you draw inside the little squares representing the relation between the three same volume cubes?	- The pupils fill in the second part of "Worksheet 3.2". - They announce their results.

WORKSHEET: 3.2

Activity 3

Intended Learning Outcomes:
Pupils get aware that the suggested representation is plausible and persuasive.

Classroom Organization:
The teacher discusses with all pupils.

TEACHER'S ACTIONS	PUPILS' ACTIONS
- The teacher presents the model "dots" as an alternative one and not as the best existing model of representation of the cubes. - The teacher assigns a specific number of dots to each of the cubes. First, to the iron cube, then the rubber cube and finally to the wood cube. - He/she compares the cubes made of other materials, he/she puts them in order: iron (9), glycerine (7), rubber (6), water (4), oil (3), wood (2), air (1). - We did not use the materials (5) and (8) because there are other materials as well.	- The pupils fill in the "Worksheet 3.3" - They discuss with the teacher.

WORKSHEET: 3.3, SOFTWARE: ROOM "WEIGHING MATERIALS 2"

3rd Episode: The visual model of density as a criterion for floating / sinking
Activity 1

Intended Learning Outcomes:
Pupils are persuaded that the proposed model of density is fruitful.

Classroom Organization:
The teacher discusses with all pupils.

TEACHER'S ACTIONS	PUPILS' ACTIONS
- Let's see if we can create a rule for floating sinking based on this crowdedness model of density. - The teacher helps the groups. - When the cube of the material has less dots that the water cube, it floats. - When the cube of the materials has more dots than the water cube, it sinks. - This means that the dots in the cube are something like identity of the each material.	- Pupils work with the «Worksheet 3.4», They experiment, discuss and answer the questions. - Pupils announce their results.

WORKSHEET: 3.4, SOFTWARE: ROOM "FLOATING SINKING OF MODELS"

UNIT 4: GENERALIZING THE CRITERION FOR FLOATING AND SINKING, NATURE AND ROLE OF MODELS

Teaching Objectives

1. The students negotiate the property of density as a criterion for floating and sinking of simple and compound objects.
2. The students negotiate aspects of the models' nature.

1st Episode: The visual model of density as a criterion for floating/sinking of the objects.

Activity 1

Intended Learning Outcomes:

(1) To confirm that the visual model of density is a criterion of floating/sinking for another liquid, too (glycerine)

(2) To generalize the floating-sinking rule for other liquids except water.

Classroom Organization:

The teacher discusses with all students and with the groups

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
- What we said in our last lesson about floating-sinking. We were looking for a criterion in order to be certain when an object sinks or not in a liquid. We came to these conclusions: - When the little cube of the material has more dots than the water cube then the material sinks into the water. - When the material cube has fewer dots than the water cube then the material floats. At the same time, the teacher demonstrates the last lesson's slide and Poster 3.	-The students answer to the teacher's questions.

WORKSHEET: 4.1, SOFTWARE: ROOM "FLOATING SINKING OF MODELS 2"

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART B	
- You came to these conclusions about f/s in water, what about other fluids, though? What can we do to check if this rule applies to another liquid e.g. glycerine? - Before the students fill in "Working paper 4.1", the teacher demonstrates the new material information on the computer. - Write in detail the steps you will follow. After that, carry out what you have already decided to do. Be careful because I want you to describe the best you can the way you are going to perform the experiment. - The teacher accepts as correct answers the ones that suggest at least one test concerning floating and one concerning sinking. - This experiment could go on with many other fluids. However, we do not proceed for brevity. Yet, we are aware that it stands for every liquid. The slide with the following 9 materials appears on the PC: iron, carbon thread, glycerine, rubber, polyurethane, wood.	-The students fill in "Working paper 4.1" - The students communicate their suggestions and their results.

WORKSHEET: 4.1, SOFTWARE: ROOM "FLOATING SINKING OF MODELS 2"

2nd Episode: The property of density concerning simple and compound objects.

Activity 1

Intended Learning Outcomes:

(1) The students learn that the more/less dots the material's little cube has the more / less dense it is.

(2) The students use the density of an object as a criterion for floating.

Classroom Organization:

The teacher discusses with all students.

TEACHER'S ACTIONS	PUPILS' ACTIONS
He/she demonstrates Poster 4 and a series of materials from the more to the less dense one in the last lesson on the PC. - To avoid repeating "dots in the material's cube" we will use "density", instead. This is how we are going to call this property, the identity of the materials, hereafter. To conclude: - The more dots a cube has, the denser it is. - What happens when the material cube has more dots? - …greater density, than the water cube, so denser than what? - …than the water density, then the material sinks. - In other words, we say that the materials that sink in a liquid are denser than the liquid. - The materials that float in a liquid are less dense than the liquid. Based on what we mentioned, let's have a look again at the material order. Which liquid does the rubber sink in? Which liquid does it float on? Why? Let's watch another example.	- The students attend the teacher's lecture. They reply in turn to his/her questions.

WORKSHEET: -

Activity 2

Intended Learning Outcomes:

(1) To understand that the density of a compound object lies between the densities of the materials that comprise this certain object.

(2) To use the density of a compound object as a criterion for floating / sinking.

Classroom Organization:

The teacher performs a demonstration experiment. The teacher discusses with all students.

TEACHER'S ACTIONS	PUPILS' ACTIONS
He/she uses an iron taw, the model of a ship, a vessel full of water. - Tell me now. If I let the taw fall into the water, what will happen? It is an iron taw (denser). - What if I let the ship? Why does it float? It is made of iron, too. What does the ship have inside? Nothing or air? Remember the water cube, the iron cube, the air cube. - So, the ship is less dense than water. - What do that taw and the ship have in common? (They are both made of iron) - What are their differences? (round, long) - If I cut the taw in half, how will its interior look like? - If I cut this ship in half, (vertically), how will its interior look like? - So, we have an object, the taw that it's made only of one material and an object that is compound (a ship made of iron and air).	- The students attend the teacher's lecture. They reply in turn to her-his questions.

WORKSHEET: -

Activity 3

Intended Learning Outcomes:

(1) To understand that the density of a compound object lies between the densities of the materials that comprise this certain object.

(2) To use the density of a compound object as a criterion for floating.

Classroom Organization:

The teacher performs a demonstration experiment. The teacher discusses with all students.

TEACHER'S ACTIONS	PUPILS' ACTIONS
He/she uses a piece of glass, an empty bottle, a vessel full of water. - Demonstration: a piece of glass – sinking. - Demonstration: the bottle - Write on your "Working Paper 4.2" your suggestions and your explanations.	- The students observe the experimental activity – demonstration. They fill in "Working paper 4.2". - The groups communicate their answers.

WORKSHEET: 4.2

3rd Episode: The concept of “model” and its value

Activity 1

Intended Learning Outcomes:

(1) To learn that a model can represent one object or a property.

(2) To learn that an object or a property can be represented with more than one model.

(3) To learn that we can predict a phenomenon by using a model.

Classroom Organization:

The teacher discuss with the all Students.

TEACHER’S ACTIONS	PUPILS’ ACTIONS
He/she shows the alternative models on the PC (lines, shadows, colours…). (Software, Room “Various Models”) - The teacher extends the meaning of the concept of model. - Recapitulation: We talk for density in order to predict when an object floats or sinks. Our basic tools were cubes E.g., do you remember that I asked you to design? What have you done? - What you have designed and suggested with your pictures were a few models to explain which material is more or less dense. - What is a model? It is something that represents a property like density. - How does it help us? How did it help us? To understand the density of materials. And to use it when predicting the floating and sinking of materials. Which material floats or sinks in a liquid. To predict. - E.g. Here’s another scientific model (heliocentric model). What do you think it represents? - It represents the earth, the sun and the moon. It shows us their position. Can we predict with that model if it’s morning or night somewhere when it’s morning in Greece? What do you think? - But, let’s see another model. Does it represent the same? (Yes) - So, we can have different models for the same thing. - He/she recapitulates the nature of a model, using a power point presentation.	- Students look at the sketches that they drew on the previous lesson on “Working paper 3.2”.

WORKSHEET: 3.2, SOFTWARE: ROOM “VARIOUS MODELS”

UNIT 5: LET'S SALVAGE SEA DIAMOND

Teaching Objectives

1. The students use the property of density as a criterion for floating and sinking of homogeneous and composite objects
2. The students solve two open technological problems

1st Episode: Density as a criterion for floating and sinking of homogeneous and composite objects

Activity 1

Intended Learning Outcomes:

-

Classroom Organization:

The teacher discusses with the students

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
Questioning - Could you please remind me the criterion that we have for floating and sinking in liquids? The teacher can use the poster "Density Criterion", just after 1-2 students refer to the criterion.	- The students discuss possible solutions on two technological problems

WORKSHEET: -

<table>
<tr><th>TEACHER'S ACTIONS</th><th>PUPILS' ACTIONS</th></tr>
<tr><td colspan="2">PART B</td></tr>
<tr><td>Questioning
- Here we have an object, a bottle. Is it a concrete object? What does it contain inside? (air)
- We have already seen a relevant experiment. What would happen if I throw the piece of glass in the water? It will sink. What would happen if I throw the bottle? It will not sink. –How could we explain this fact according to what we have already discussed until now? Does this bottle consist of one material? No it consists of glass and air.
- Did we conclude that the density criterion can be used for composite objects as well? Yes. Could we repeat the criterion? If a composite object floats in water then this object's density is smaller than water's density.
- What should we think for the density of a composite object?
- This bottle's density, which consists of glass and air, will be in between the density of glass and the density of air. Taking into account the fact that this bottle floats in water we can also say that its density should be smaller than water's density.
- Does its size affect floating or sinking of this bottle? Which object is bigger, the bottle, which floats, or the piece of glass, which sinks?</td><td>- The students discuss possible solutions on two technological problems</td></tr>
</table>

WORKSHEET: -

2nd Episode: Floating and sinking of a simulation of a ship

Activity 1

Intended Learning Outcomes:
Students learn to recognize the components of a model.

Classroom Organization:
The teacher discusses with the students. The students work in groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
Questioning - The teacher prompts students to perform the simulated experiment using the software.	- The students fill the "Worksheet 5.1" - They announce their conclusions.
- What you see on the computer (software) is a real ship? How do we call it? A model of a ship. What information does it provide? In which aspects of the ship does it focus? -Από ποια στοιχεία αποτελείται αυτό το μοντέλο του SD? - How do these holds function? How do we use them? - Which is the relevance between SD's density and water's density when SD floats? - Which is the relevance between SD's density and water's density when SD sinks? - What happens when we remove water from the holds? Which material replaces water? - What is this model useful for?	- They continue working according to the Worksheet, and more specifically filling the questions about models.

WORKSHEET: 5.1, SOFTWARE: ROOM "SEA DIAMOND"

3rd Episode: The hauling up of a statue

Activity 1

Intended Learning Outcomes:

-

Classroom Organization:
The teacher discusses with the students. The students work in groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
Questioning - The teacher prompts students to perform the experiment in two phases. In the first phase she asks students to propose solutions. In the second phase she gives them the worksheet with the two proposals.	- The students fill the "Worksheet 5.2" - They announce their conclusions.

WORKSHEET: 5.2

4rth Episode: The hauling up of a ship

Activity 1

Intended Learning Outcomes:

-

Classroom Organization:
The teacher discusses with the students. The students work in groups.

TEACHER'S ACTIONS	PUPILS' ACTIONS
PART A	
Questioning - This is the model of a ship that we have already seen. Let's sink it. - Other students have already proposed that using the materials that you see on your desks we can haul up the ship. Could you think a way so as to pull up the ship? Try to support your proposal using the conclusions about floating and sinking. In the first phase she asks students to propose solutions. In the second phase she gives them the worksheet with the two proposals.	- The students fill the "Worksheet 5.3" - They announce their conclusions.

WORKSHEET: 5.3

C: EVALUATION TASKS

C: EVALUATION TASKS

1. RATIONALE OF THE ASSESSMENT

The research questions of this study are the following:

1. To what extent do the students acquire declarative (a. explanations for floating and sinking phenomena, b. understanding of the concept of density) knowledge?
2. To what extent do the students acquire procedural and epistemological (a. Control of Variables Strategy and b. aspects of nature and role of models as well as modelling skills) knowledge?
3. Is there correlation between the learning, on the one hand, of procedural and epistemological knowledge and, on the other hand, of the learning of the declarative knowledge?
4. Which are the learning pathways that were followed by specific students during the implementation?

The multiple sources of data, which are being collected over the intervention period, include classroom video recordings, field notes, students' artefacts, pre and post-questionnaires and semi-structured clinical interview transcripts. In addition, we collected audio recordings of each student group work and used suitable open source software to record students' group work in particular computer-based tasks. Pre and post-questionnaires are the main data for our quantitative analysis of students' learning outcome. Video and audio recordings as well as semi-structured clinical interview transcripts are the main data that will be used, after the transcript and the conversion in text, in a qualitative way so as: a. to validate the findings revealed by the analysis of the data of the questionnaires and b. to reveal the learning pathways of the students. The rest of the data, namely field notes, students' artefacts and students' group work software records, will give us the possibility to triangulate assertions generated from both quantitative and qualitative analysis.

The procedure of data collecting that we followed is the following: One week before each application, students answer/fill in the pre-questionnaire. Similarly, one week after the last lesson, students fill in the pre-questionnaire. No later than ten days after the last lesson, the interviews are conducted as well. In the fixed application, students will additionally fill in two intermediate questionnaires (one after the second lesson and one after the fourth) aiming at the safest emergence of students' learning pathways of knowledge.

The tasks that are used in every pre and post-questionnaire aim, as mentioned before, to reveal the ideas of students concerning four basic questions, before and after the application. The comparison and analysis of the data of the above questionnaires aim to control learning in accordance with these four questions. In the table below, we can briefly see the correspondence of the tasks that were used in the questionnaires with the research questions.

EMERGENCE OF STUDENTS' IDEAS ON:	TASKS PREQN	TASKS INTERQN1	TASKS INTERQN2	TASKS POSTQN	TASKS POSTIQN
1. Explanations for floating and sinking phenomena	1.a, 1.b, 1.c, 1.d	1.a, 1.b, 1.c, 1.d	1.e (*), 1.f (*)	1.a, 1.b, 1.c, 1.d, 1.e (*), 1.f (*)	
2. Understanding of the concept of density	2.a, 2.b, 2.c, 2.d	2.a, 2.b, 2.c, 2.d	2.a, 2.b, 2.c, 2.d, 2.e (*), 2.f (*),	2.a, 2.b, 2.c, 2.d, 2.e (*), 2.f (*),	2.g, 2.h, 2.i, 2.j, 2.k, 2.l
3. Learning of Control of Variables Strategy	3.a	3.a, 3.b (*)		3.a, 3.b (*)	3.c, 3.d, 3.e, 3.f
4. Learning of models and modelling	4.a, 4.b, 4.c		4.a, 4.b, 4.c, 4.d (*), 4.e (*)	4.a, 4.b, 4.c, 4.d (*), 4.e (*), 1.d, 1.e	4.f, 4.g, 4.h, 4.i

With (*) are signed the questions that do not exist in the PreQN questionnaire

TABLE 1: CORRESPONDENCE OF THE TASKS OF THE QUESTIONNAIRES WITH THE QUESTIONS.

Moreover, the questionnaire for the interview after the application (PostIQN) includes, as we can see in the table, only tasks concerning the three last questions but not in relation to the first one. This is because it was considered that, on the one hand, the last two research questions could not have clear and safe results on learning of the respective procedural or epistemological knowledge and on the other hand that the second research question could not be fully researched, concerning the differentiation of the concepts of weight and density, just from the tasks of the pre and post questionnaires. Thus, it was considered necessary to collect additional data through semi - structured interviews. Besides the tasks of the interview questionnaire that are mentioned in table 1, the interview questionnaire also includes tasks that hold an explorative role in relation to the extent of acquiring aspects of the technological problem solving. Following, we describe and discuss the tasks that are included in the post questionnaire and in the Interview Questionnaire. The tasks that are included in Pre, Interim1, Interim2 as well as PostPost Questionnaires are part of the Post Questionnaire Task Analysis. Thus, we do not refer separately to them. Nevertheless, in each task's analysis we refer the questionnaires that the task is included. PostPost Questionnaire is similar to the Post Questionnaire. The questionnaires – tasks correspondence is analytically presented in table 1.

2. POST QUESTIONNAIRE TASK ANALYSIS

TASK 1: EXPLANATIONS FOR FLOATING AND SINKING PHENOMENA

TASK 1.A: FLOATING / SINKING – F / S EXPLANATIONS

This pre, interim1 & post - questionnaire task examines the explanations that the students give concerning (a) floating (of the life buoy) and (b) sinking (of the anchor) phenomena.

TASK 1AA (LIFE BUOY) AND 1AB (ANCHOR)

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Object – liquid density comparison: The response implies using of causal relational reasoning.	*"The life buoy floats because its density is smaller than the liquid's density".*
2	Refer to the material: The response implies that the student understands that f/s is determined by the material of the object. It also implies using of causal linear reasoning.	*I agree with Marie.*
3	Refer to the weight or the volume of the object: The response implies that the student assumes that f/s is determined by the weight, volume, shape. It also implies using of causal linear reasoning.	*"The anchor sinks because it is heavy".*
4	Refer to the existence of air in the object: The response implies that the student assumes that f/s is determined by the existence of air in the object. It also implies using of causal linear reasoning.	*"The life buoy floats because it has air in it".*
5	Irrelevant answers, answers with internal inconsistencies, teleological answers or no answers.	*"The life buoy floats because it is made to save people".*

TASK 1.B: ALTERNATIVE IDEAS ABOUT F / S

This pre, interim1 & post - questionnaire task examines to which extent the students use causal relational or causal linear reasoning, using figure 1. Students should decide which factor to change in order that the plasticine ball floats.

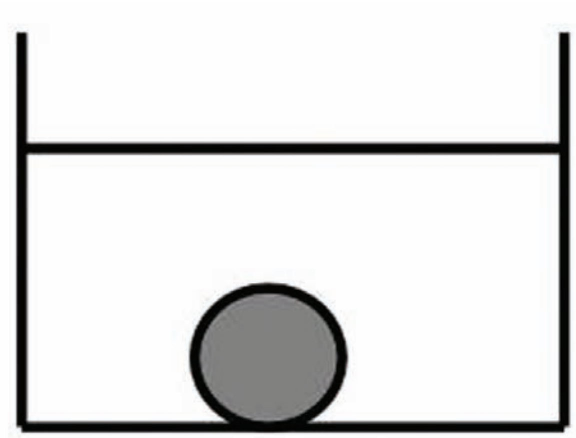


FIGURE 1: A PLASTICINE BALL IN A TANK FILLED WITH WATER

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Change of factors that imply causal relational reasoning (factors could be the liquid or the liquid and the material of the object).	*"I would change the liquid".*
2	Change of factors that imply causal linear reasoning (factors could be the weight, the size, the volume, the material of the object).	*"I would cut it in two pieces and then it would float".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*".....”*

TASK 1.C: ALTERNATIVE IDEAS ABOUT F / S PHENOMENA – WEIGHT OR SIZE

This pre, interim1 & post - questionnaire task examines if the students have the alternative idea about floating and sinking that a big object will sink and a small will float, using figure 2. The 2nd icon gives the opportunity to the students to choose the swinging of an object as another situation except from the floating or sinking. It plays the role that the answer "I do not know" has in other tasks.

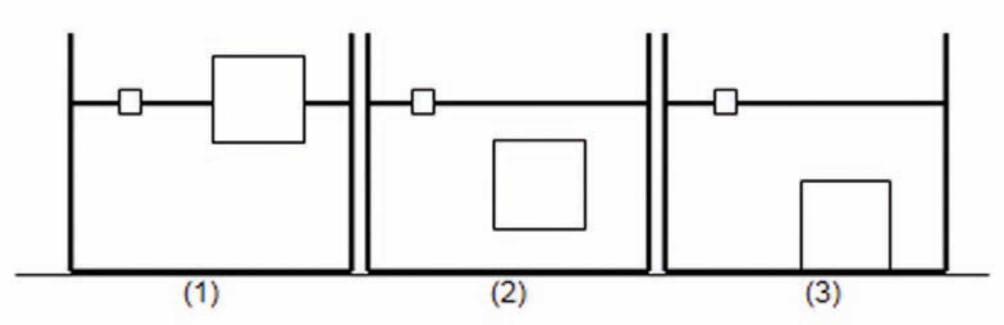


FIGURE 2: FLOATING SINKING ALTERNATIVE IDEAS

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Refer to the material: Usually the students of this category choose the 1st icon. The choice illustrates understanding of the importance of the material concerning the floating sinking of an object. The explanation that the students provide, implies understanding of this importance.	*"I chose the 1st icon because the two objects are made of the same material".*
2	Refer to the weight or the size of the object: Usually the students of this category choose the 3rd icon and more rarely the 2nd one. This response illustrates alternative ideas (size or the weight of an object as a cause) concerning the f / s of the object.	*"I would cut it in two pieces and then it would float".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*"I chose the 1st icon because the object is bigger and thus it will float" or "…because I want them both on the surface".*

TASK 1.D: ALTERNATIVE IDEAS ABOUT F / S PHENOMENA – WIDTH OF THE TANK

This pre, interim1 & post – questionnaire task examines if the students have the alternative idea about floating and sinking that the width of the vessel influences the phenomenon, using figure 3. The 3rd icon gives the opportunity to the students to choose the swinging of an object as another situation except from the floating or sinking. It plays the role that the answer “I do not know” has in other tasks.

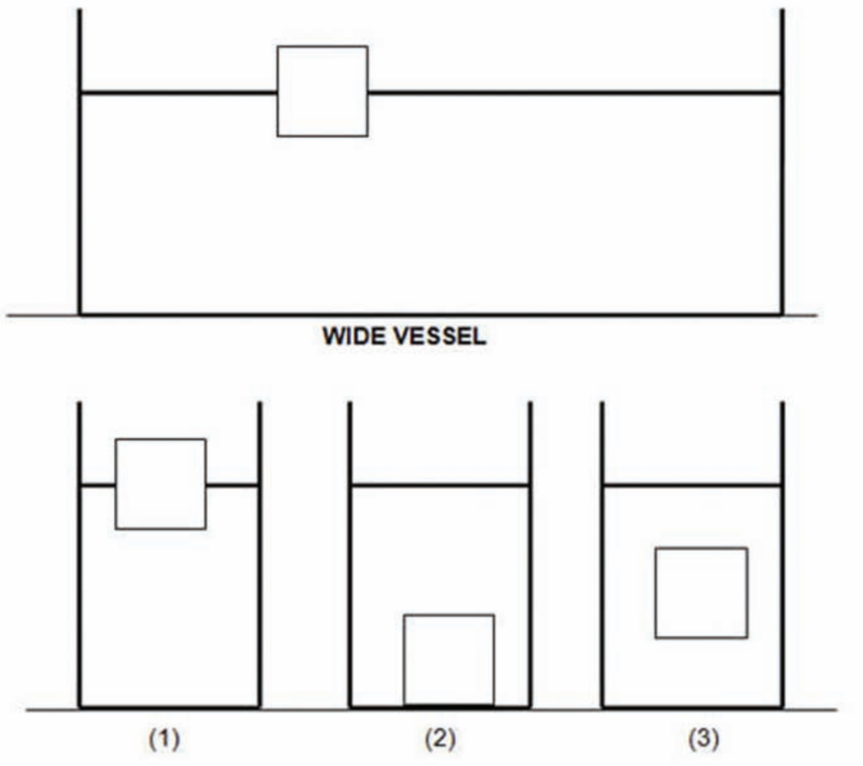


FIGURE 3: FLOATING SINKING ALTERNATIVE IDEAS

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Refer to the material: Usually the students of this category choose the 1st icon. The choice illustrates understanding that the width of the tank plays no role to the f/s phenomenon. The explanation that the students provide, implies understanding of this fact.	*“I chose the 1st icon because if the object floats in the narrow tank it floats in the wide tank as well”.*
2	Refer to the width of the tank: Usually the students of this category choose the 2nd icon and more rarely the 3rd one. This response illustrates alternative ideas (width of the tank as a cause) concerning the f / s of the object.	*“I chose the 2nd icon because the water is less and the object is heavy”.*
3	Irrelevant answers or answers with internal inconsistencies or no answers.	*“I chose the 3rd icon because I believe that the object’s density is the same with liquid’s density” or “…..”.*

TASK 1.E: USE OF THE "CROWDEDNESS MODEL" TO EXPLAIN AND PREDICT F / S

This interim2 & post - questionnaire task examines if the students use the "crowdedness model" in order to explain and predict the floating and / or sinking of an object in a liquid or if they still, after the implementation, refer to their alternative ideas, using figure 4.

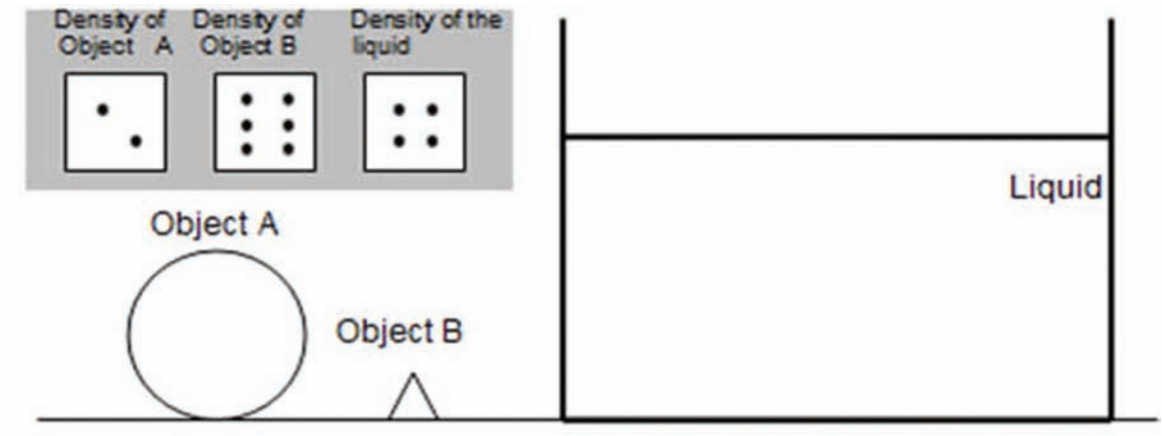


FIGURE 4: USE OF THE "CROWDEDNESS MODEL"

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use of the "crowdedness model" in an object – liquid density comparison procedure: The response implies use of causal relational reasoning. Students draw object A floating and object B sinking.	*"Object A will float because its density is less than liquid's density. Object B will sink because its density is bigger than liquid's density"*
2	Use of the "crowdedness model" just referring the object's density: The response implies use of causal linear reasoning. Students draw object A floating and object B sinking.	*Object A will float because it has small density. Object B will sink because it has big density."*
3	Refer to the weight or the volume of the object: The response implies that the student assumes that f/s is determined by the weight, volume, shape. It also implies using of causal linear reasoning. Students draw object B floating and object A sinking.	*"Object A will sink and object B will float"*
4	Irrelevant answers or answers with internal inconsistencies	*"Object A will float because it is bigger" or "….."*

TASK 1.F: USE OF THE "CROWDEDNESS MODEL" TO COMPARE THE FLOATING PLANE OF OBJECTS

This interim2 & post - questionnaire task examines if the students use the "crowdedness model" in order to decide if an object floats higher, lower or in the same line with another one, in a liquid or if they still, after the implementation, refer to their alternative ideas, using figure 5.

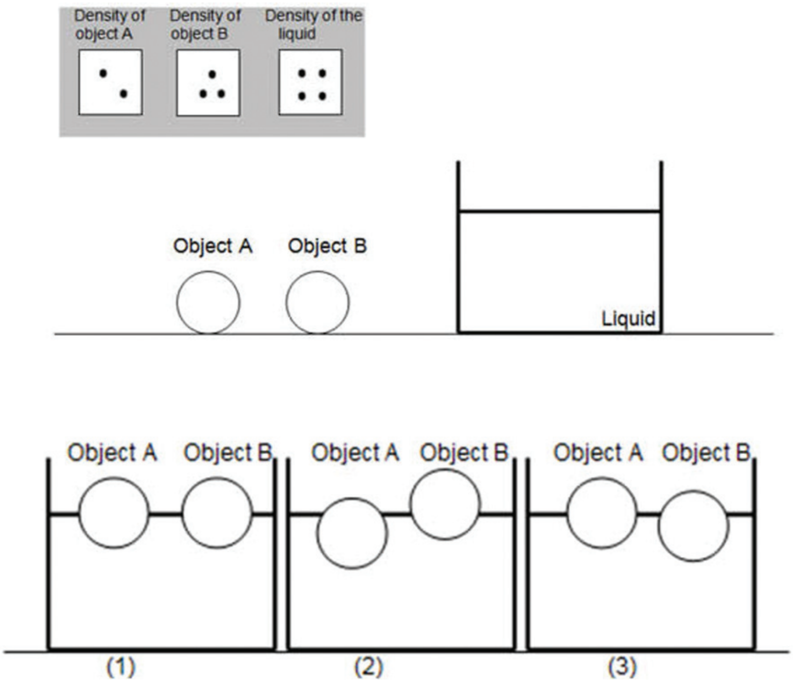


FIGURE 5: USE OF THE "CROWDEDNESS MODEL"

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use of the "crowdedness model" in an object – liquid density comparison procedure, different floatation planes: The response implies use of causal relational reasoning and understanding of the possibility of different floatation plane for each object comparing its densities. Students choose icon 3.	*"Object's B density is smaller than the liquid's so it will float. Object's A density is even smaller so it will float a little bit higher (icon 3)".*
2	Use of the "crowdedness model" in an object – liquid density comparison procedure, no different floatation planes: The response implies use of causal relational reasoning but not understanding of the possibility of different floatation plane for each object. Students choose icon 1.	*"Both of the objects will float as in icon 1 because both have smaller density than the liquid (icon 1)".*
3	Irrelevant answers or answers with internal inconsistencies. Students choose mostly the icon 1.	*"It could have different liquid and float (icon 1)".*

TASK 2: UNDERSTANDING OF THE CONCEPT OF DENSITY

TASK 2.A: UNDERSTANDING OF THE CONCEPT OF DENSITY

This pre, interim1, interim2 & post - questionnaire task examines if the students have any idea on the concept of density, asking them to write down a sentence with the word density and material.

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Density as a property of materials: The response implies understanding of the correlation between the material of an object and its density concerning f/s phenomenon.	*"A material's density influences its floating or sinking in a liquid".*
2	Density with the meaning of dense: The response implies that the students remain in a phenomenological approach of the concept of density in several contexts.	*"If a liquid is very dense you cannot see through it" or "The leaves of a tree are many and so they are very dense".*
3	Irrelevant answers or answers with internal inconsistencies.	*"The materials are dense because they are fresh".*

TASK 2.B: ALTERNATIVE IDEAS ABOUT THE CONCEPT OF DENSITY – SHAPE OF THE OBJECT

This pre, interim1, interim2 & post - questionnaire task examines if the students connect density with the material or if they refer to alternative ideas such as that the shape of the object or even its weight determines its density, using figure 6. Students are informed that the two objects are made from the same material and the same amount.

FIGURE 6: ALTERNATIVE IDEAS ABOUT THE CONCEPT OF DENSITY

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Density related to the material: The response implies that the students relate the concept of density with the kind of material from which the object is made of. Students choose option C.	*“Both have the same density because they are made from the same material”.*
2	Density related to the weight or the shape of the object: The response implies that the students have the alternative idea that density is related to the weight or the shape of the object. Students choose option A or B or even option C.	*“Both have the same density because they are made from the same amount of this material ” or “The sphere has bigger density because it is bigger”.*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*“I do not know» or “the cube has bigger density because it has many right curves”.*

TASK 2.C: ALTERNATIVE IDEAS ABOUT THE CONCEPT OF DENSITY – SIZE OF THE OBJECT

This pre, interim1, interim2 & post - questionnaire task examines if the students connect density with the material or if they refer to alternative ideas such as that the shape or the volume, size of the object determines its density, using figure 7.

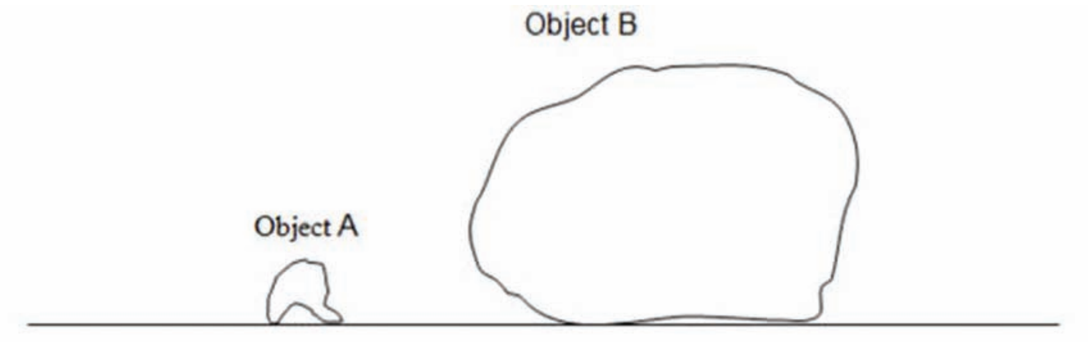


FIGURE 7: ALTERNATIVE IDEAS ABOUT THE CONCEPT OF DENSITY

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Density related to the material: The response implies that the students relate the concept of density with the kind of material from which the object is made of. Students choose option C.	*"Both objects have the same density because they are from the same material".*
2	Density related to the weight of the object: The response implies that the students have the alternative idea that density is related to the weight of the object. Students choose option B.	*"Object B has more density than object A because it is bigger".*
3	Density related to the volume of the object: The response implies that the students have the alternative idea that density is related to the volume of the object. Students choose option A.	*"Object A has more density than object B because it is smaller and narrower".*
4	Irrelevant answers, no answers or answers with internal inconsistencies.	*"I do not know" .*

TASK 2.D: USE OF THE F / S OF AN OBJECT IN A LIQUID TO COMPARE OBJECT'S DENSITY IN DIFFERENT SITUATIONS

This pre, interim1, interim2 & post - questionnaire task examines if the students use the floating or sinking of an object in a liquid in order to to compare object's density in different situations, using figure 8. The student has to take under consideration the floating or sinking of the object in the sea, in both cases, in order to compare and decide in which of the two cases the submarine has bigger density or if its density remains constant.

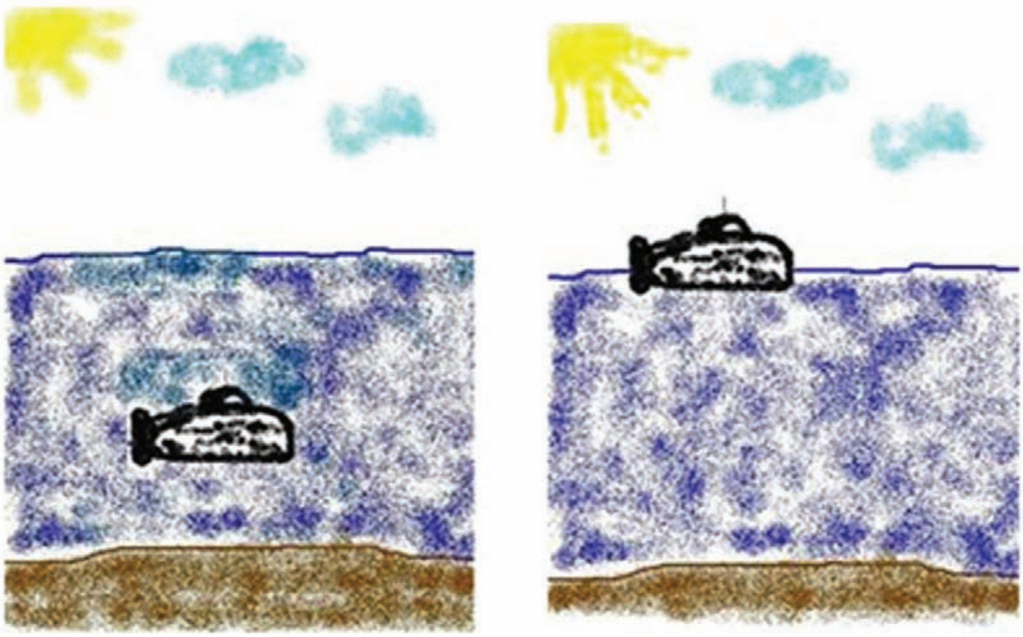


FIGURE 8: ALTERNATIVE IDEAS ABOUT THE CONCEPT OF DENSITY

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use the floating or sinking of an object in a liquid in order to decide for its density. Students choose option A.	*"The submarine in figure 1 has bigger density than in figure 2 because in figure 2 it is floating".*
2	Use alternative criteria in order to decide for the density of an object. For instance, "the same object the same density" rule (option C).	*"The submarine has the same density in both figures because it is the same object".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*"The submarine has bigger density on the surface because it is better for the crew".*

TASK 2.E: USE OF THE F / S OF AN OBJECT IN A LIQUID TO COMPARE OBJECT'S DENSITY IN DIFFERENT SITUATIONS OR TO COMPARE OBJECT'S DENSITY WITH LIQUID'S DENSITY

This interim2 & post - questionnaire task examines if the students use the floating or sinking of an object in a liquid to compare object's density in different situations or to compare object's density with liquid's density, using figure 9. The students have to answer three questions in this task. The first is similar to the task 2.d, and asks students to decide if object A has bigger density than object B. It is a prerequisite that the students compare, at first, each object's density with the liquid's density in order to answer this question. The other questions, ask students to compare an object's (A or B) density with the liquid's density. The students should now use the information of the f / s of an object in the liquid. The categories, though, in all three cases are the same as follows.

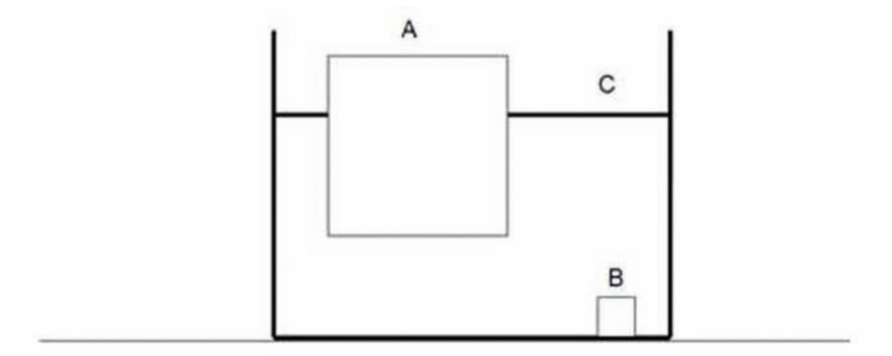


FIGURE 9: USING FLOATING SINKING IN ORDER TO CONCLUDE FOR AN OBJECTS' DENSITY

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use the floating or sinking of an object in a liquid in order to decide for its density. Students choose option A.	*"Object A has smaller density than object B because object A is floating and object B is sinking in the same liquid".*
2	Use alternative criteria in order to decide for the density of an object. For instance, the bigger the object the more the density.	*"Object B has smaller density than object A because it is smaller".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*"Object's B density is not greater than liquid's density because the shape does not influence the f/s phenomenon".*

TASK 2.F: UNDERSTANDING OF THE SWINGING OF A OBJECT IN A LIQUID

This interim2 & post - questionnaire task examines if the students understand the swing of an object in a liquid as a different state than floating and sinking and if they use this state in order to decide for its density, using figure 10.

FIGURE 10: USING SWINGING IN ORDER TO CONCLUDE FOR AN OBJECTS' DENSITY

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use the swinging of an object in a liquid in order to decide for its density. Students choose SOFIA's quotation.	*"The object and the liquid have the same density because the object does not sink neither floats".*
2	The students do not understand the swinging of an object as another situation than floating and sinking.	*"The liquid has more density than the object because it does not float".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*"I do not know".*

TASK 3: LEARNING OF CONTROL OF VARIABLES STRATEGY

TASK 3.A: CONTROL OF VARIABLES STRATEGY, CVS, SAME PROBLEM, A VARIABLE NEGOTIATED DURING THE IMPLEMENTATION

This pre, interim1 & post - questionnaire task examines to which extent the students learn the control of variables strategy – same problem, a variable negotiated during the implementation. Students should describe (a) the procedure to control a variable and (b) the procedure to draw a conclusion taking under consideration the results of the experiment, in other words their observations).

TASK 3AA (CONTROL)

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Control one variable keeping the others constant and making observations.	*"I would use a tank with water and a tank with oil. I would throw in them the same object and observe what happens in order to control if the liquid influences the f / s of an object".*
2	Control one variable keeping the others constant.	*"I would take two tanks with different liquid and an object and I would throw it in them".*
3	Control two or more variables simultaneously or just refer to the realization of an experiment.	*"I would take oil, water, vinegar and other liquids and I would throw in them a piece of paper" or "I would make the experiment.*
4	Refer to their opinion instead of the process to control the variable.	*"I agree with George because the kink of the liquid influences the f / s of an object".*
5	Irrelevant answers, no answers or answers with internal inconsistencies.	*"….."*

TASK 3AB (DRAW A CONCLUSION)

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Comparison of the results of the experiment.	*"If the object would float in one tank and sink in the other then I would say that the kind of liquid influences the phenomenon".*
2	Mention the evaluation of the results of the experiment.	*"I would make the experiment and observe".*
3	Mention their conclusion or the procedure of control the variable instead of the procedure to conclude.	*"It does not influence".*
4	Irrelevant answers, no answers or answers with internal inconsistencies.	*"….."*

TASK 3.B: CONTROL OF VARIABLES STRATEGY, CVS, SAME PROBLEM, A VARIABLE NOT NEGOTIATED DURING THE IMPLEMENTATION

This interim1 & post - questionnaire task examines to which extent the students learn the control of variables strategy – same problem, a variable not negotiated during the implementation. Students should describe (a) the procedure to control a variable and (b) the procedure to draw a conclusion taking under consideration the results of the experiment, in other words their observations). The categories of response in each subtask are similar with those of the task 3.a.

TASK 4: LEARNING OF MODELS AND MODELLING

TASK 4.A: UNDERSTANDING OF THE CONCEPT OF MODEL

This pre, interim2 & post - questionnaire task examines if the students have any idea on the concept of model, asking them to write down a sentence with the word model.

TASK 3AB (DRAW A CONCLUSION)

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	The model as a representation of a target.	*"A model is a representation and not a copy of the object".*
2	The model as a tool for instruction.	*"We use models in experiments in the class".*
3	The model as an object or a concept for recreation.	*"My sister will become a model" or "My father will buy the new model of Audi".*
4	Irrelevant answers, no answers or answers with internal inconsistencies.	*"….."*

TASK 4.B: NATURE AND ROLE OF MODELS, PHYSICAL MODEL

This pre, interim2 & post - questionnaire task examines to which extent the students learn basic aspects of the nature and the role of models (physical), using figure 11. Students should write down (a) which is the use of this construction and (b) how would they name it.

FIGURE 11: A PHYSICAL MODEL OF AN EYE

TASK 4BA (USE OF THE CONSTRUCTION – ROLE OF MODELS)

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	This construction helps to explain or predict a phenomenon.	*“It can help us to know how is our eye constructed and to know what to do if something happens to our eye”.*
2	This construction can be used in experiments or to understand in a case of instruction.	*“It can help us to see the interior of our eye”.*
3	This construction can be used in a recreational way.	*“We could construct a robot”.*
4	The construction cannot be distinguished from the reality.	*“It is useful for us and for the animals because this way we can see”.*
5	Irrelevant answers, no answers or answers with internal inconsistencies.	*“......”*

TASK 4BB (NAME OF THE CONSTRUCTION – NATURE OF MODELS)

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	The student recognizes the construction as a model, thus as a representation of a target.	*"The model of an eye".*
2	The student recognizes the construction as a tool for instruction.	*"It is like a map".*
3	The student recognizes the construction as an object or a concept for recreation.	*"The monster's eye" or "James Bond construction".*
4	The construction cannot be distinguished from the reality.	*"It is an eye".*
5	Irrelevant answers, no answers or answers with internal inconsistencies.	*"....."*

TASK 4.C: NATURE AND ROLE OF MODELS, SKETCH

This pre, interim2 & post - questionnaire task examines to which extent the students learn basic aspects of the nature and the role of models (sketch), using figure 12. Students should write down which is the use of this construction and how would they name it. The categories of response in each subtask are similar with those of the task 4.b.

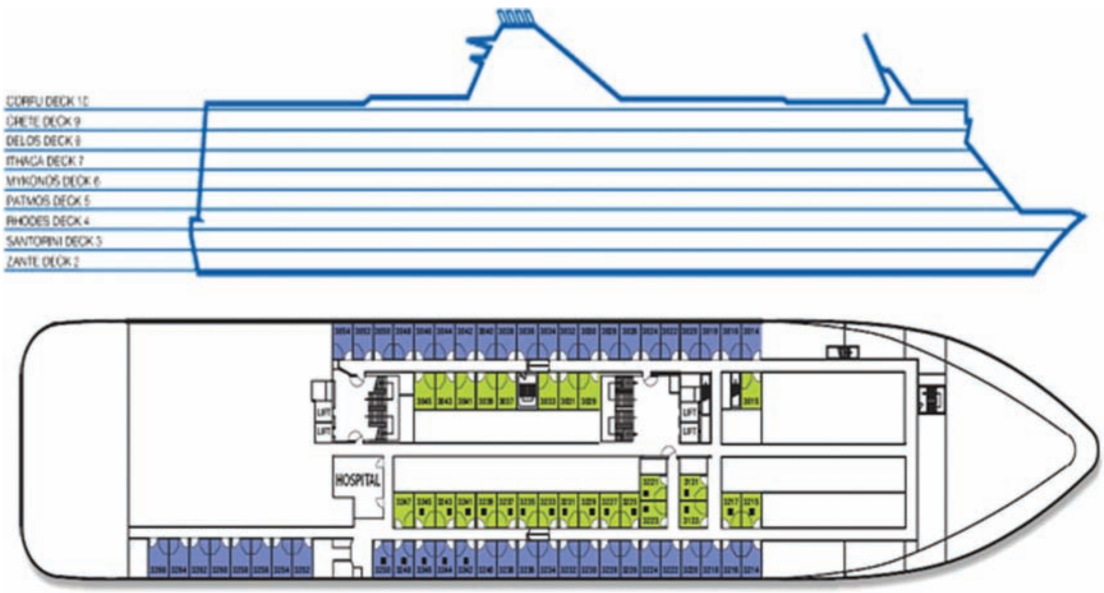


FIGURE 12: TWO MODELS OF A SHIP (SKETCH)

TASK 4.D: NATURE AND ROLE OF MODELS, VISUAL STATIC MODEL

This interim2 & post - questionnaire task examines to which extent the students learn basic aspects of the role of models (visual), using figure 13. Students should write down which is the use of this visual model. The categories of response in each subtask are similar with those of the task 4.ba.

FIGURE 13: THE VISUAL “CROWDEDNESS” MODEL OF DENSITY

TASK 4.E: MODELLING SKILLS, COMPARING MODELS OF THE SAME TARGET

This interim2 & post - questionnaire task examines to which extent the students acquire basic modelling skills (comparing models of the same target), using figure 14. Students should write down what made them choose the “dots model” instead of the “shades model”.

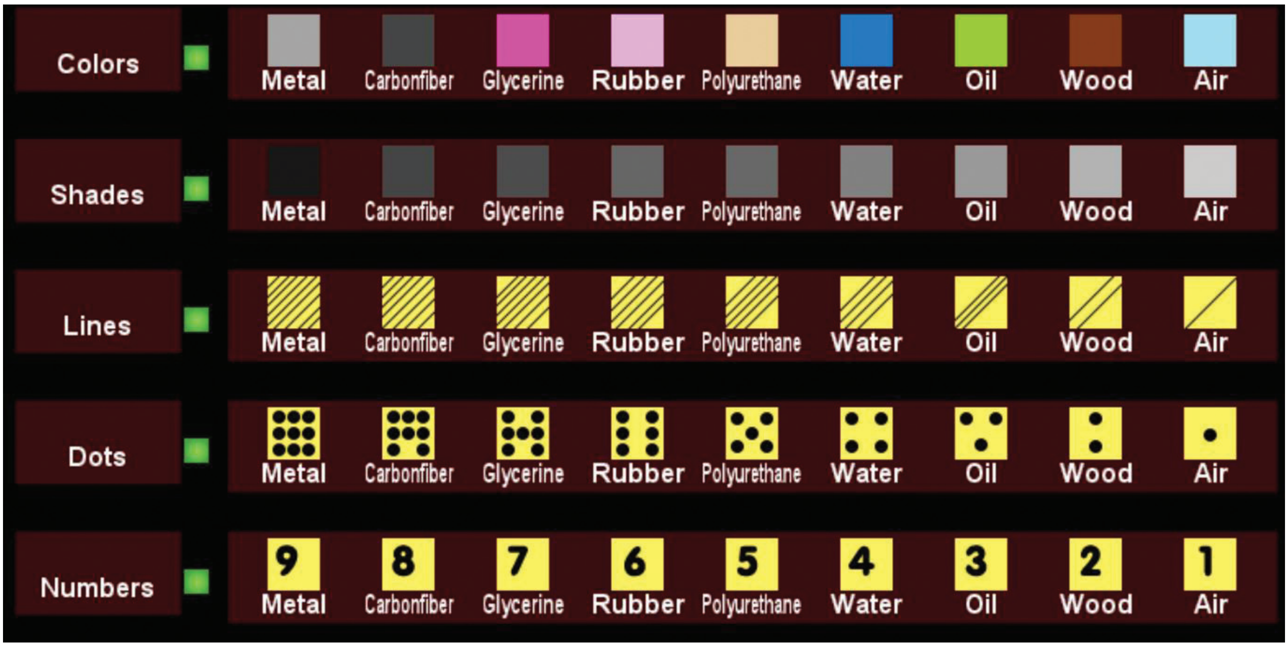


FIGURE 14: VARIOUS VISUAL REPRESENTATIONS OF DENSITY

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Compare the two models in relation with their practical use in order to predict the f/s of several objects.	*“Because it is easier to make the comparison between two cubes. If we used the shades we could not distinguish them as easily as with the dots”.*
2	Compare the two models in relation to the easiness to remember them.	*“Because it helps us to remember the density of the materials”.*
3	No difference: The response implies that the students cannot find any difference between the two representations.	*“We could choose the shades instead of the dots. It would be the same”.*
4	Irrelevant answers, no answers or answers with internal inconsistencies.	*“…..”*

3. SEMI STRUCTURED CLINICAL INTERVIEW TASK ANALYSIS

There are no questions in the interview, concerning explanations for floating and sinking phenomena for two reasons: first, we assumed that the answers that students give in the written questionnaires are adequate and second, because we can implicitly gather information about this subject through other questions e.g. questions concerning Control of Variables Strategy. Thus, we begin with task number 2 in order to keep the correspondence with the relevant post tasks as well as with the relevant research questions.

TASK 2: VALIDATION OF DISTINCTION BETWEEN WEIGHT AND DENSITY

Students are shown figure 15, and are asked to work according to the description of the following six subtasks. The first four subtasks, 1a, 1b, 1c and 1d have only the role to prepare the student in order to work in the subtasks 1e and 1f which are the two subtasks that the students' answers are categorized and evaluated. This evaluation will reveal if the students differentiate the concepts of weight and density. If they use the tank with water in order to compare densities and the balance in order to compare weights of several objects we assume that they differentiate these two concepts.

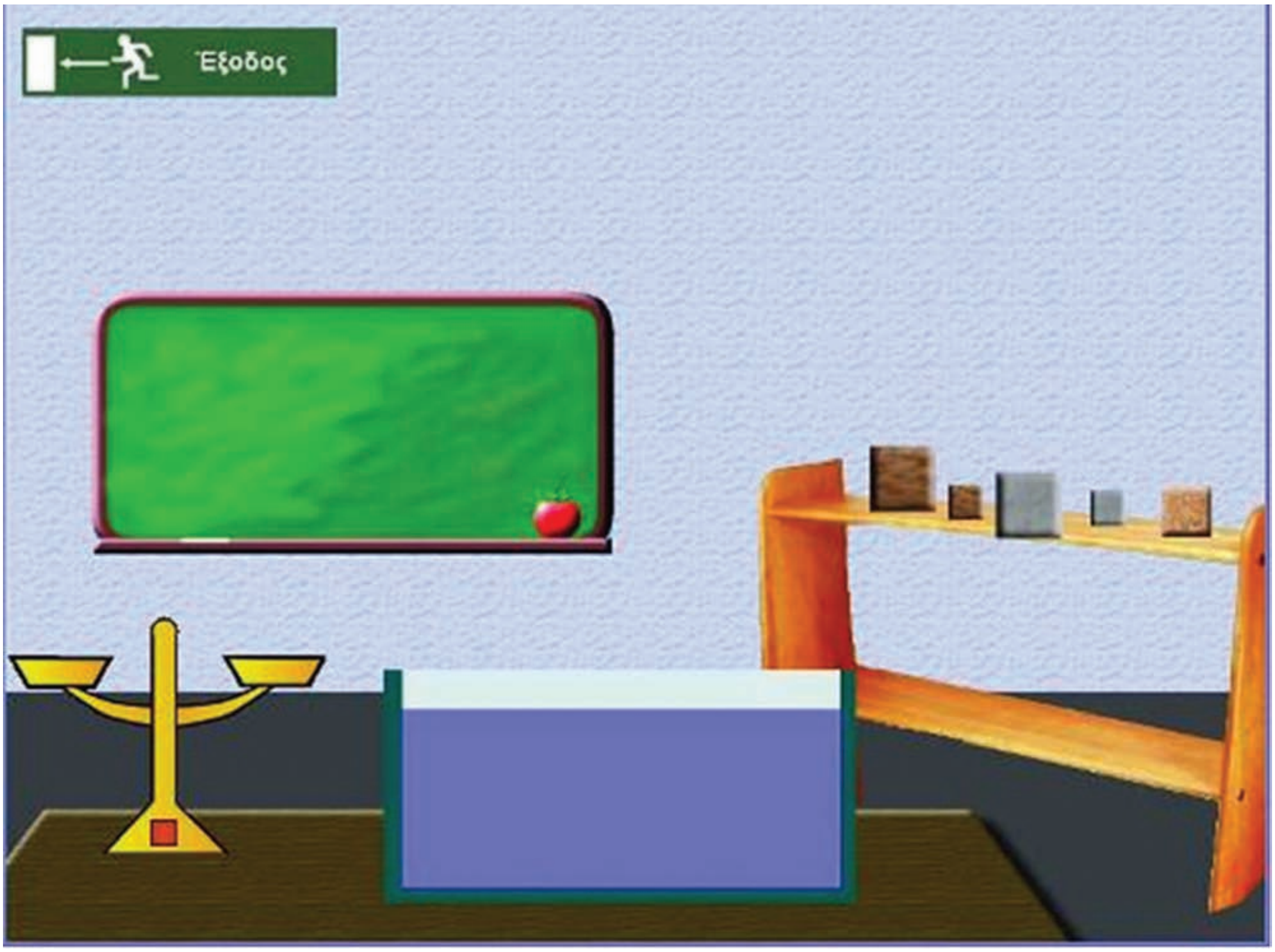


FIGURE 15: THE SCREENSHOT FOR THE WEIGHT AND DENSITY COMPARISONS OF SEVERAL OBJECTS

TASK 2G: COMPARISON OF THE WEIGHT OF THE IRON CUBES

Students are asked to compare the weight of the two iron cubes

TASK 2H: COMPARISON OF THE WEIGHT OF THE WOODEN CUBES

Students are asked to compare the weight of the two wooden cubes

TASK 2I: COMPARISON OF THE DENSITY OF THE IRON CUBES

Students are asked to compare the density of the two iron cubes

TASKS 2J: COMPARISON OF THE DENSITY OF THE WOODEN CUBES

Students are asked to compare the density of the two wooden cubes

TASK 2K: COMPARISON OF THE WEIGHT OF THE CORK CUBE AND THE WEIGHT OF EACH OF THE TWO WOODEN CUBES

Students are asked to compare the weight of the cork cube and the weight of each of the two wooden cubes. Afterwards, they are asked to propose a procedure, using either the balance or the tank with water or both of them, in order both to control if their suggestion is right and to persuade the interviewer.

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use of the balance to compare the weight of the objects.	*"In order to compare the weight of the cork cube and the weight of the big wooden cube I would put them on the balance" .*
2	Use either the balance or the tank with water to compare the weight of the objects. It does not make any difference.	*"In order to compare the weight of the cork cube and the weight of the big wooden cube I would put them either on the balance or on the tank with water. It is the same".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*"……."*

TASK 2L: COMPARISON OF THE DENSITY OF THE CORK CUBE AND THE DENSITY OF EACH OF THE TWO WOODEN CUBES

Students are asked to compare the density of the cork cube and the density of each of the two wooden cubes. Afterwards, they are asked to propose a procedure, using either the balance or the tank with water or both of them, in order both to control if their suggestion is right and to persuade the interviewer.

	CATEGORY OF RESPONSE	TYPICAL STUDENT RESPONSE
1	Use of the tank with water to compare the density of the objects.	*"In order to compare the density of the cork cube and the density of the small wooden cube I would put them on the tank with water and I would see if they float or sink".*
2	Using either the balance or the tank with water to compare the density of the objects. It does not make any difference.	*"In order to compare the density of the cork cube and the density of the small wooden cube I would put them on the tank with water and I would see if they float or sink. I could also put them on the balance to compare their densities".*
3	Irrelevant answers, no answers or answers with internal inconsistencies.	*"……."*

TASK 3: VALIDATION OF LEARNING THE CONTROL OF VARIABLES STRATEGY

TASK 3C: A VARIABLE ALREADY CONTROLLED DURING THE APPLICATION

This interview task examines to which extent the students learn the control of variables strategy – same problem, a variable negotiated during the implementation. Students should describe (a) the procedure to control a variable and (b) the procedure to draw a conclusion taking under consideration the results of the experiment, in other words their observations). The categories of response in each subtask are similar with those of the pre and post questionnaire's task 3.a.

TASK 3D: THE SAME PROBLEM, DIFFERENT VARIABLE

This interview task examines to which extent the students learn the control of variables strategy – same problem, a variable not negotiated during the implementation. Students should describe (a) the procedure to control a variable and (b) the procedure to draw a conclusion taking under consideration the results of the experiment, in other words their observations). The categories of response in each subtask are similar with those of the pre and post questionnaire's task 3.a.

TASK 3E: DIFFERENT PROBLEM, KNOWN VARIABLE

This interview task examines to which extent the students learn the control of variables strategy – different problem, known variable. Students should describe (a) the procedure to control a variable and (b) the procedure to draw a conclusion taking under consideration the results of the experiment, in other words their observations). The categories of response in each subtask are similar with those of the pre and post questionnaire's task 3.a.

TASK 3F: DIFFERENT PROBLEM, UNKNOWN VARIABLE

This interview task examines to which extent the students learn the control of variables strategy – same problem, unknown variable. Students should describe (a) the procedure to control a variable and (b) the procedure to draw a conclusion taking under consideration the results of the experiment, in other words their observations). The categories of response in each subtask are similar with those of the pre and post questionnaire's task 3.a.

TASK 4: VALIDATION OF LEARNING OF MODELS AND MODELLING SKILLS

TASK 4F: NATURE AND ROLE OF MODELS – MODELS ABOUT DENSITY THAT WERE USED IN THE SOFTWARE

The aim of this task is to reveal the extent to which the students learn basic aspects of models that were used in the TLS – visual model of density (if they recognize it as a model and if they refer to its explanatory and predictive role). The categories of response in each subtask are similar with those of the pre and post questionnaire's task 4.b.

TASK 4G: MODELLING SKILLS – MODELS ABOUT DENSITY THAT WERE USED IN THE SOFTWARE

The aim of this task is to reveal the extent to which the students acquire, specific modelling skills, (implicit) knowledge that were not taught during the TLS implementation – comparison of models that describe the same target (visual model of density).

TASK 4H: NATURE AND ROLE OF MODELS – A MODEL NOT DEALT WITH DURING THE IMPLEMENTATION OF THE MODULE

The aim of this task is to reveal the extent to which the students learn basic aspects of models that were not used in the TLS – water cycle (if they recognize it as a model and if they refer to its explanatory and predictive role). The categories of response in each subtask are similar with those of the pre and post questionnaire's task 4.b.

TASK 4I: MODELLING SKILLS – A MODEL NOT DEALT WITH DURING THE IMPLEMENTATION OF THE MODULE

The aim of this task is to reveal the extent to which the students acquire, specific modelling skills, (implicit) knowledge that were not taught during the TLS implementation – development of models (drawings) representing a bicycle, mention the elements of the models and the reason to include these ones. Students are asked to recognize the constituents of a water cycle model. They are also asked to decide if it is necessary to include more constituents, and they are free to improve the model according to their previous decision.

TASK 5: VALIDATION OF ACQUISITION OF THE PROCEDURAL (TECHNOLOGICAL PROBLEM SOLVING) KNOWLEDGE

TASK 5A: PUPILS ASKED TO IMPROVE THE SOLUTIONS SUGGESTED DURING THE COURSE

The aim of this task is to reveal the extent to which the students acquire, specific skills concerning the procedural knowledge of solving a technological problem. During the fifth unit of the TLS the students have already negotiated with the solutions that the archaeologists and the environmentalists proposed in order to salvage a statue from the sea. Thus, in order to evaluate the acquisition of basic relevant skills we request students to improve the solutions that have already been suggested in the lesson. (USA's National Research Council, 2000)

4. QUESTIONNAIRES

4.1. QUESTIONNAIRES ENCODING

The questionnaires that we use are:

Paper and pencil questionnaires:

1. Pre Questionnaire Normal → PreQN, includes the following tasks: 1.a, 1.b, 1.c, 1.d, 2.a, 2.b, 2.c, 2.d, 3.a, 4.a, 4.b, 4.c
2. Intermediate Questionnaire Normal 1 → InterQN1, includes the following tasks: 1.a, 1.b, 1.c, 1.d, 2.a, 2.b, 2.c, 2.d, 3.a, 3.b
3. Intermediate Questionnaire Normal 2 → InterQN2, includes the following tasks: 1.e, 1.f, 2.a, 2.b, 2.c, 2.d, 2.e, 2.f, 4.a, 4.b, 4.c, 4.d, 4.e
4. Post Questionnaire Normal → PostQN, includes the following tasks: 1.a, 1.b, 1.c, 1.d, 1.e, 1.f, 2.a, 2.b, 2.c, 2.d, 2.e, 2.f, 3.a, 3.b, 4.a, 4.b, 4.c, 4.d, 4.e
5. PostPost Questionnaire Normal → PostPostQN, includes the following tasks: 1.a, 1.b, 1.c, 1.d, 1.e, 1.f, 2.a, 2.b, 2.c, 2.d, 2.e, 2.f, 3.a, 3.b, 4.a, 4.b, 4.c, 4.d, 4.e

Oral interview questionnaire:

1. Post Interview Questionnaire Normal → PostIQN, includes the following tasks: 2.g, 2.h, 2.i, 2.j, 2.k, 2.l, 3.c, 3.d, 3.e, 3.f, 4.f, 4.g, 4.h, 4.i

Normal refers to the Normal implementation because we had a pilot one as well. Following, are presented the tasks that constitute the questionnaires.

4.2. PAPER AND PENCIL QUESTIONNAIRES' TASKS

TASK 1.A

On a big ship, among others, you can find: life-buoy and anchor. Which of them do you think that float and which sink if we drop them on the sea? Justify your answer.

The life-buoy: floats ☐ sinks ☐ I do not know ☐

Why:

....

....

The anchor: floats ☐ sinks ☐ I do not know ☐

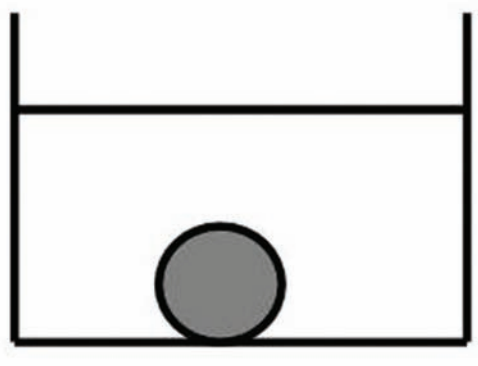
Why:

....

....

TASK 1.B

A. In the picture we see a ball made of plasticine, which is sunken in a tank filled with water. Could you change a feature (factor) so that the ball floats? Describe which feature you would change and in which way.



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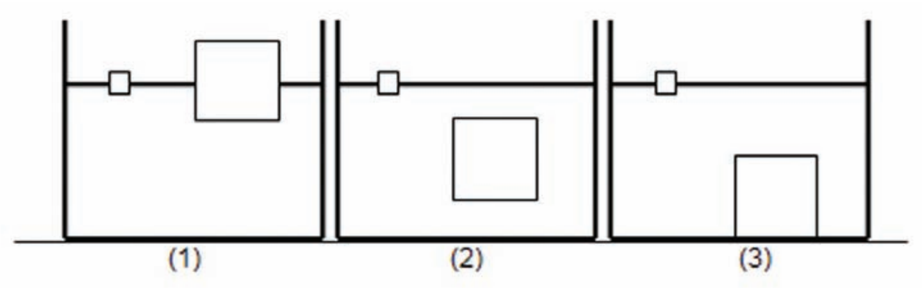
TASK 1.C

Costas drops a small piece of a material in a vessel filled with water and he observes that it floats. Afterwards, Irene drops a big piece of the same material in the same vessel. In your opinion, where will the big piece stop moving? Check the number 1, 2 or 3 of the picture that you think it represents the final position of the two bodies that Costas and Irene dropped in the vessel.



Justify your choice:

....

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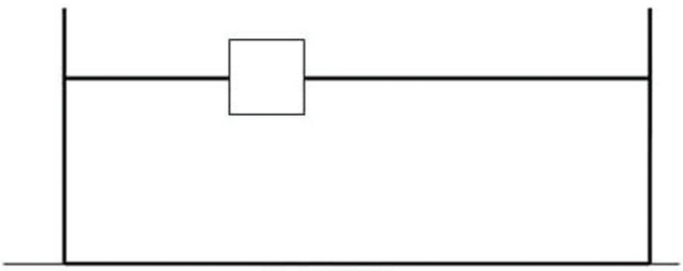
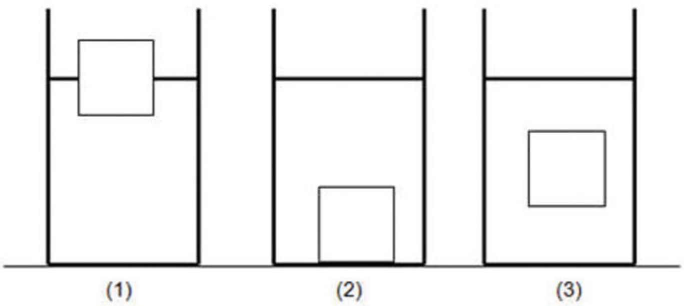
....

TASK 1.D

Costas dropped the cube in the liquid which is in the wide vessel shown below and the cube floats. Irene dropped the same cube in a narrow vessel, containing the same liquid. In your opinion, where will the cube stop moving in the narrow vessel? Check the number 1, 2 or 3 of the picture that you think it represents the final position of the cube that Irene dropped in the narrow vessel.



WIDE VESSEL

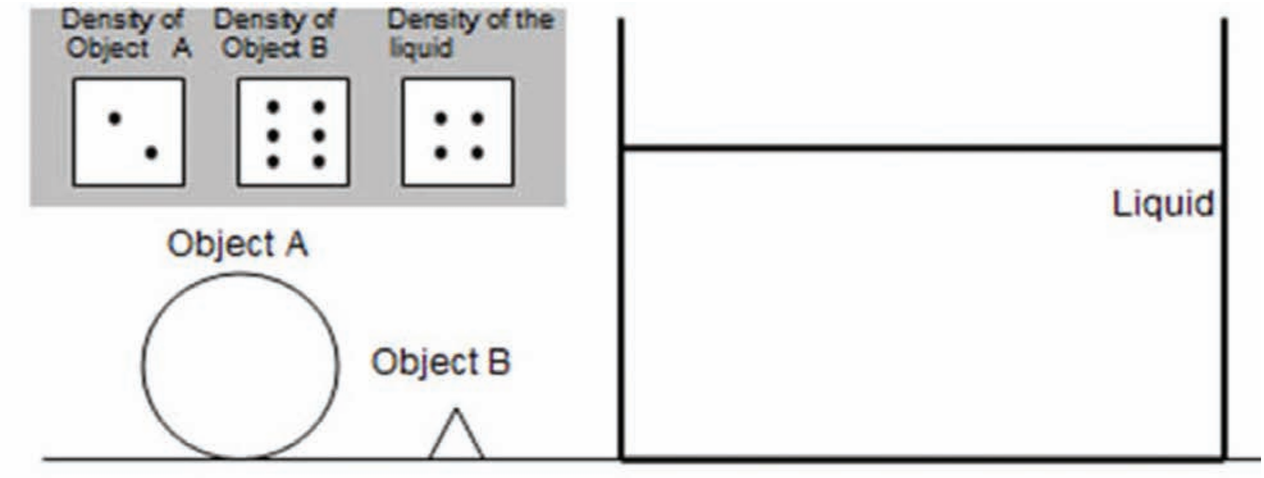


NARROW VESSEL

Justify your choice:

TASK 1.E

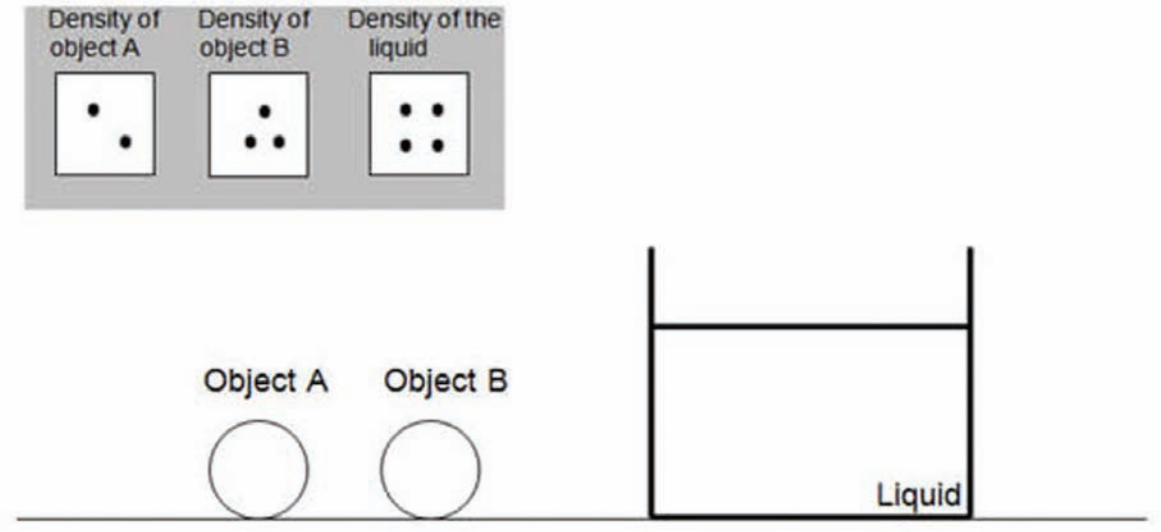
You are given two objects A and B and a vessel which contains a liquid. Both objects' and liquid's densities are represented with "the cubes with dots" model, as you can see on the grey panel. If you drop the objects A and B on the vessel with the liquid, which do you think that will be their final position?



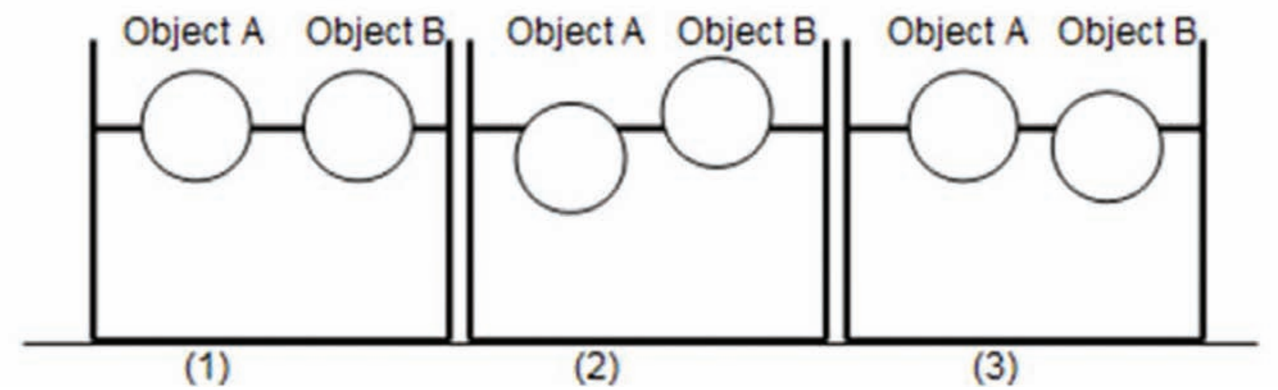
Justify your choice:

Could you draw the objects A and B at their final position in the liquid?

TASK 1.F



Both objects' and liquid's densities are represented with "the cubes with dots" model, as you can see on the grey panel. We drop the objects A and B on the liquid. Check the number 1, 2 or 3 of the picture which you think it represents the final positions of the two objects after we drop them in the liquid.



Justify your choice:

....

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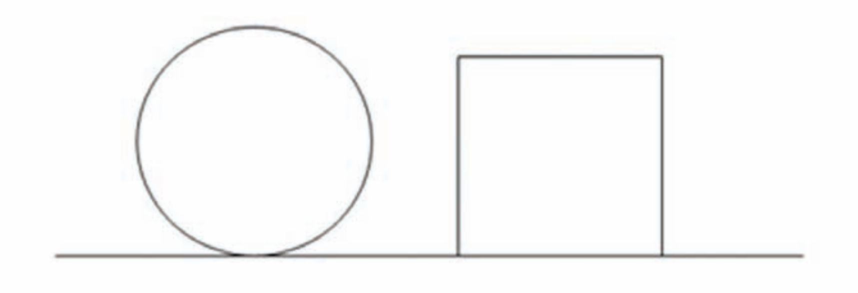
TASK 2.A

Write **a** sentence, the most representative for you, including both the words: **density** and **material**. You can put them inside the sentence in any order you want.?

TASK 2.B

On the picture you can see two objects of the same material. In order to construct this ball and this cube we used the same quantity of the same material. These two objects have the same quantity of material.



Which of the following sentences do you agree with?

A. The ball has greater density than the cube ☐

B. The cube has greater density than the ball ☐

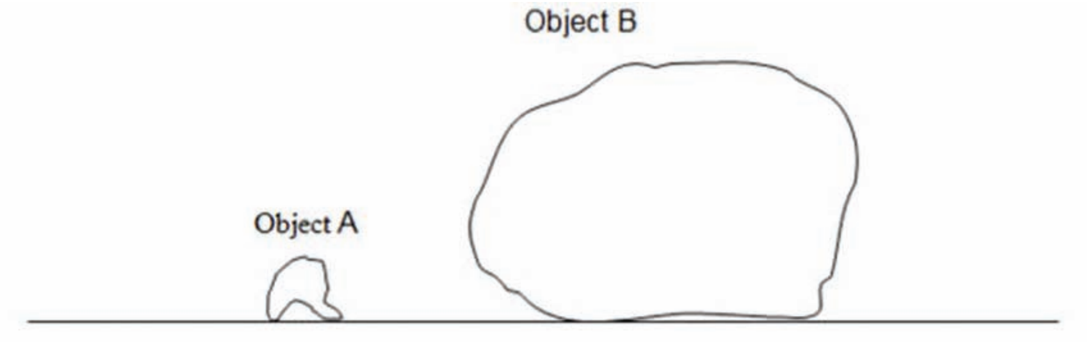
C. Both of them have the same density ☐

D. I do not know ☐

Justify your choice:

TASK 2.C

On the picture you can see two objects of the same material: plastic.



Which of the following sentences do you agree with?

A. Object A has greater density than object B ☐

B. Object B has greater density than object A ☐

C. Both of them have the same density ☐

D. I do not know ☐

Justify your choice:

....

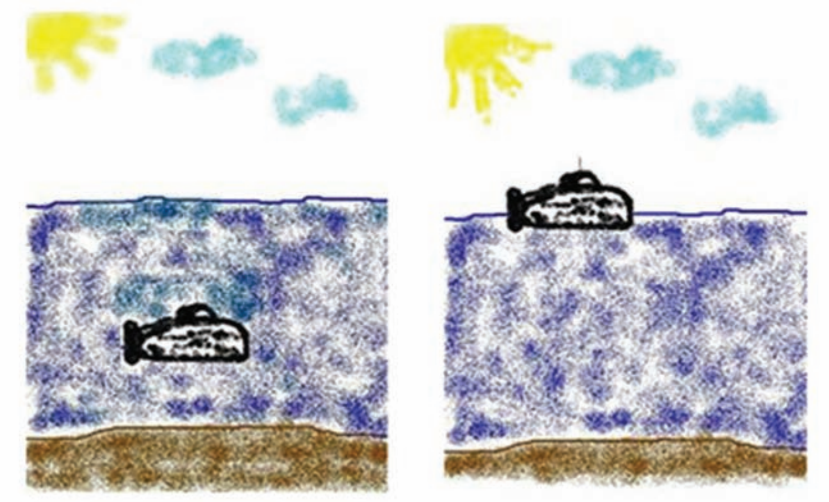
....

....

....

TASK 2.D

On the picture 1 you can see one submarine that is inside the sea. On the picture 2 the same submarine has ascent on the surface of the sea so that the sailor enjoy the sunny day.



1 2

Which of the following sentences do you agree with?

A. Submarine in picture 1 has greater density than in picture 2 ☐

B. Submarine in picture 2 has greater density than in picture 1 ☐

C. The submarine has the same density on both pictures ☐

D. I do not know ☐

Justify your choice:

....

....

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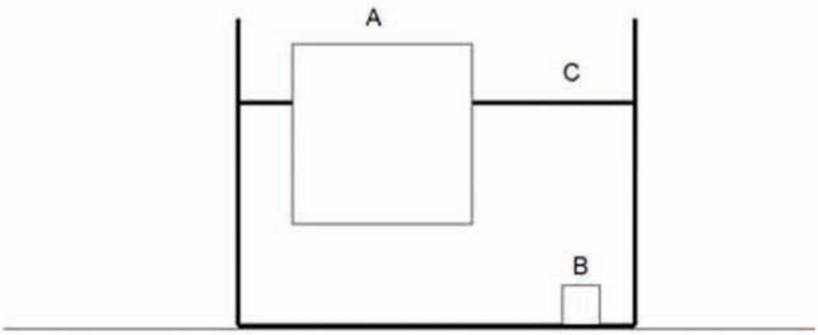
....

TASK 2.E

We drop the two objects A and B in the liquid C. Object A floats on liquid C whereas object B sinks in liquid C. Decide if the following sentences are right or wrong:



1. Object A has greater density than object B.

   True ☐ False ☐ I do not know ☐

   Why:

   ....

   ....

2. Object B has greater density than the liquid C.

   True ☐ False ☐ I do not know ☐

   Why:

   ....

   ....

3. Object A has greater density than the liquid C.

   True ☐ False ☐ I do not know ☐

   Why:

   ....

   ....

TASK 2.F

While Georgia, Sofia and Petroula were playing with some toys, a toy was left by mistake inside a vessel with the liquid as we can see at the picture. Then, they noticed that this toy was going neither on the surface of the liquid nor to the bottom of the vessel. They were wondering about the density of the toy:
Georgia says that this object has greater density than the liquid.
On the other hand, Petroula thinks that this object has smaller density than the liquid.
Sofia says that the object and the liquid have the same density.

Whom of the following students do you agree with?

Georgia ☐ Petroula ☐ Sofia ☐ I do not know ☐

Why:

....

....

TASK 3.A

George said that «…the kind of the liquid in a vessel affects the floating or sinking of a body in this liquid…», whereas Maria said the opposite, that is «…the floating or sinking of a body in this liquid is independent of the kind of the liquid in the vessel…». If you want to find out who of the two students is right, what would you do to check their opinions.

....

....

....

....

If you realized the above proposals you would draw some conclusion.
Describe how you would come to this conclusion.

....

....

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....

TASK 3.B

A group of children discuss about the factors that can influence the floating and sinking of an object in a liquid inside a vessel. Someone from them says that probably it is influenced by the kind of surface of the object: rough or smooth. This means whether the object has or not protrusions. Can you describe what you would do to check it?

If you realized the above proposals you would have come to a conclusion.
Describe how you would come to this conclusion.

TASK 4.A

Write a sentence, the most representative for you, including the word **model**.

(1)

TASK 4.B

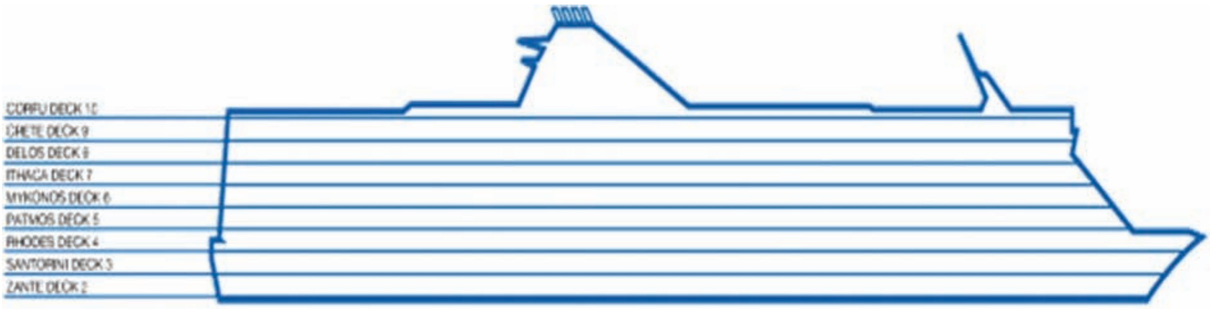
Below you can see a construction which represents a human eye.

How do you think this construction could be useful?

How would you call the above construction?

TASK 4.C

Below you see a sketch of a ship on which you can see the decks / floors from which it is consisted. On the second sketch, you can see one of these decks/floors, as it is seen from above. These sketches are hanged on the door of the apartments.



How do you think that these sketches could be useful?

....

....

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How would you call the above sketches?

....

....

....

....

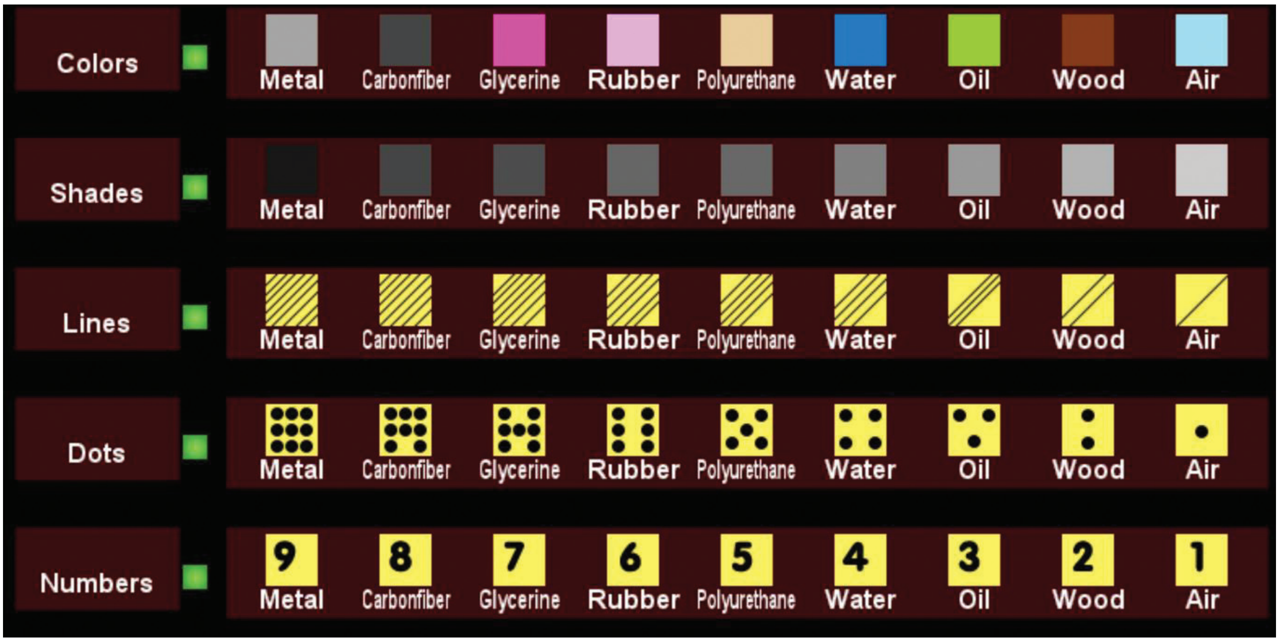
TASK 4.D

Below you can see the model "cube with dots" that we use to represent density.

How could this model of density be useful?

TASK 4.E

On the below picture you can see all the models that we saw during the lessons, about density.

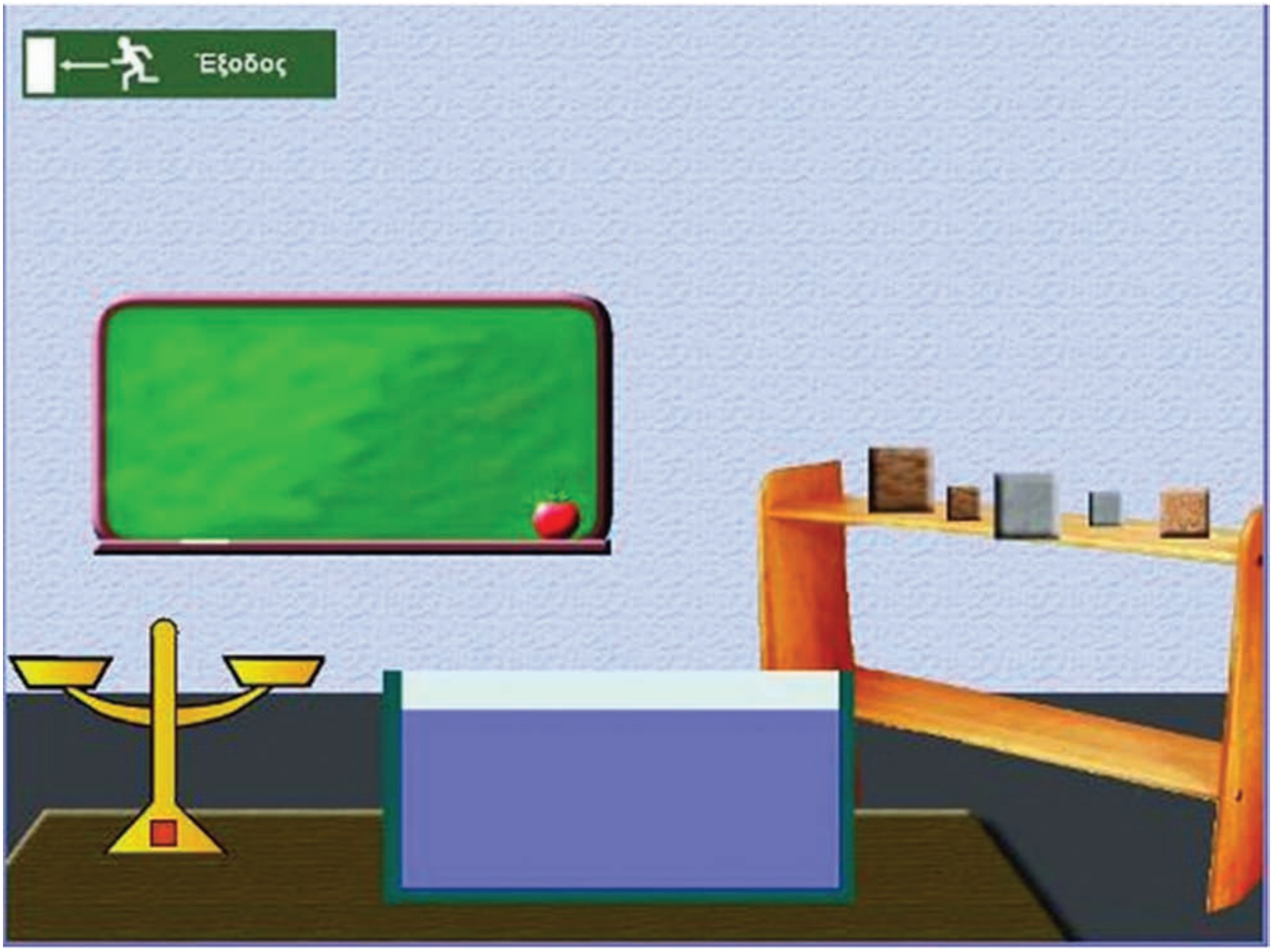


Why do you think we chose the model «cube with dots» and not the model «cube with shadows»?

4.3. ORAL SEMI – STRUCTURED CLINICAL POST INTERVIEW QUESTIONNAIRE (POSTIQN)

TASK 2: VALIDATION OF DISTINCTION BETWEEN WEIGHT AND DENSITY

On the computer screen (Picture 1), you can see two wooden cubes, two iron cubes and a cork cube. Also, you have a balance and a vessel filled with water.



PICTURE 1

TASK 2.G: COMPARISON OF THE WEIGHT OF THE IRON CUBES

Let us talk first about the two iron cubes. Bring them in front of the computer screen. A classmate tells you that the bigger cube has greater weight. Another says that the smaller cube has greater weight and a third one says that both cubes have the same weight.

Who do you agree with?

Can you explain your answer?

TASK 2.H: COMPARISON OF THE WEIGHT OF THE WOODEN CUBES

Let us talk first about the two wooden cubes. Bring them in front of the computer screen. A classmate tells you that the bigger cube has greater weight. Another says that the smaller cube has greater weight and a third one says that both cubes have the same weight.

Who do you agree with?

Can you explain your answer?

TASK 2.I: COMPARISON OF THE DENSITY OF THE IRON CUBES

Let us talk first about the two iron cubes. Bring them in front of the computer screen. A classmate tells you that the bigger cube has greater density. Another says that the smaller cube has greater density and a third one says that both cubes have the same density.

Who do you agree with?

Can you explain your answer?

TASK 2.J: COMPARISON OF THE DENSITY OF THE WOODEN CUBES

Let us talk first about the two wooden cubes. Bring them in front of the computer screen. A classmate tells you that the bigger cube has greater density. Another says that the smaller cube has greater density and a third one says that both cubes have the same density.

Who do you agree with?

Can you explain your answer?

TASK 2.K: COMPARISON OF THE WEIGHT OF THE CORK CUBE AND THE WEIGHT OF EACH OF THE TWO WOODEN CUBES

Now, let us have the cork cube.
Can you tell me whether the cork cube has greater or smaller weight than the big wooden cube?

Can you tell me whether the cork cube has bigger or smaller weight than the small wooden cube?

How do you know it? Can you do something to convince me?

TASK 2.L: COMPARISON OF THE DENSITY OF THE CORK CUBE AND THE DENSITY OF EACH OF THE TWO WOODEN CUBES

We keep on talking about those three cubes.
Can you tell me whether the cork cube has bigger or smaller density than the big wooden cube?

Can you tell me whether the cork cube has bigger or smaller density than the small wooden cube?

How do you know it? Can you do something to convince me?

TASK3: VALIDATION OF LEARNING THE CONTROL OF VARIABLES STRATEGY

TASK 3.C: A VARIABLE ALREADY CONTROLLED DURING THE APPLICATION

Let's say that you want to check whether the shape of a compact (and homogeneous) object affects its floating or sinking in a liquid in a vessel.

A. Can you describe what would you do to check it?

In case pupils do not answer fully, we can help/evaluate them by means of the following questions:

- Could we test with one object made of iron and another made of wood?

- Could the one object of the test be heavier than the other?

B. Let's say that you tried your suggestions. Then, you would draw some conclusions. Describe how you would think, so that to get to a safe conclusion.

TASK 3.D: THE SAME PROBLEM, DIFFERENT VARIABLE

A group of children discuss about the factors affecting floating or sinking of an object in a liquid which is in a vessel. One of them says that floating or sinking may depend on the material the vessel is made of. That is, if the vessel is made of iron, objects will sink, whereas if it is made of wood, objects will not sink.

A. Can you describe what would you do to check it?

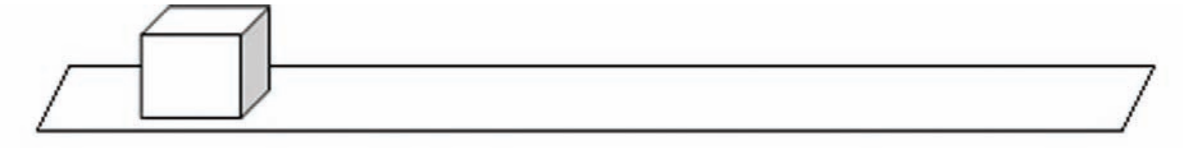
In case pupils do not answer fully, we can help/evaluate them by means of the following questions:

- Could the two vessels of the test contain different liquids?
- Should they have the same size or could it be different?
- If the object you will use floats, do you think that you will need to check what will happen with an object that sinks as well or it is not necessary?

B. If you were to experiment with the above suggestions with the other children, you would draw some conclusion. Describe how you would think, so that to get to a safe conclusion.

TASK 3.E: DIFFERENT PROBLEM, KNOWN VARIABLE

A group of children were playing with a box filled with sand. After some time, they started wondering and then arguing whether the weight of the box affects how far the box will get when pushed to move on a wooden board. They even agreed that the box shall be pushed with the same "momentum".



A. Describe what you would suggest them to do so that they check who is right.

....

....

In case pupils do not answer fully, we can help/evaluate them by means of the following questions:

- Could they use some other box filled with less sand?

....

....

B. If you were to experiment with the above suggestions with the other children, you would draw some conclusion. Describe how you would think, so that to get to a safe conclusion.

....

....

TASK 3.F: DIFFERENT PROBLEM, UNKNOWN VARIABLE

The same group of children keep on wondering whether there is another factor affecting how far the box will get when pushed.

A. Can you suggest another factor than the weight of the object that we previously suggested?

....

....

B. Describe what you would suggest they do to validate it.

....

....

In case pupils do not answer fully, we can help/evaluate them by means of the following questions:

- Does the board affects in some way?
- Does the box affects in some way?
- What if we had a rough board and a smooth one?

C. If you were to experiment with the above suggestions with the other children, you would draw some conclusion. Describe how you would think, so that to get to a safe conclusion.

TASK 4: VALIDATION OF LEARNING OF THE NATURE OF MODELS AND OF MODELLING SKILLS

TASK 4.F: NATURE AND ROLE OF MODELS – MODELS ABOUT DENSITY THAT WERE USED IN THE SOFTWARE

Below, you see the figure we used to represent density.

4. Do you remember how we call this figure?
5. What did the model of density helped us with? Which is its use? How did we use it?
6. Did we find other similar models about density? Which? If you want, draw one of these models so that I understand. That is, can we have more than one models for density (we show the Picture 1 of the Index)?

TASK 4.G: MODELLING SKILLS – MODELS ABOUT DENSITY THAT WERE USED IN THE SOFTWARE

Why do you think we chose the model with the dots and not that with the shadows or the colours?

Which are their differences?

Between the model with the shadows and the model with colours, which one do you think helps us more to predict whether an object floats or sinks in a liquid?

Explain your answer.

(Skill: Comparison of models that describe the same phenomenon)

TASK 4.H: NATURE AND ROLE OF MODELS – A MODEL NOT DEALT WITH DURING THE IMPLEMENTATION OF THE MODULE

On the computer screen you see a figure (Picture 2) which describes the water cycle.

1. How would you name this figure?
2. What does this model help us with? What is it useful for?

TASK 4.I: MODELLING SKILLS – A MODEL NOT DEALT WITH DURING THE IMPLEMENTATION OF THE MODULE

A. Can you draw a model representing a bicycle? Then, mention the elements that you chose to include in this model. Can you explain why did you choose to include these very elements in your model?
(Skill: Model development)

B. Can you mention as many elements as you think that are included in this model (water cycle)? Can you explain why these elements exist in this model?
(Skill: Recognition of the structuring elements of a model)

C. Do you think that this model includes all information that one needs to understand the route of the water and the reason it follows this route?
Can you improve this model so that it includes all missing information that you suggested as necessary?
(Skill: Evaluation and improvement of a model)

TASK 5: VALIDATION OF ACQUISITION OF THE PROCEDURAL (TECHNOLOGICAL PROBLEM – SOLVING) KNOWLEDGE

TASK 5.A: PUPILS ARE ASKED TO IMPROVE THE SOLUTIONS SUGGESTED DURING THE COURSE

Do you remember the problem that emerged when archaeologists discovered a precious statue near the region where Sea-Diamond sank? We saw that environmentalists and archaeologists were anxious that several dangerous substances may leak and destroy the statue.

A. Two solutions were suggested. Do you remember them?

....

....

If pupils do not remember them, we cite them:

- Environmentalists suggested making a life-buoy with a net because it can be made quickly and without spending a lot of money.
- Archaeologists suggested making a box so that they get sure that the statue will not bump across the rocks while it is pulled up from the bottom of the sea. However, this box needs more time and money to be constructed than the life-buoy with the net.

....

....

B. We saw that with the solution suggested by the environmentalists it was possible to have the statue lifted from the bottom of the vessel (or the sea). Nevertheless, archaeologists insist on their suggestion. They want to improve it.

How would you advise them if you belonged in their team?
Can you tell me or draw which improvements they could make?

If pupils cannot answer, then I ask the following questions:
If the archaeologists changed the material the box is made of or filled the box with air:
What would they gain and what would they lose from these changes?
Describe what you would suggest to them in order that they try their suggestion.

C. In the same time, environmentalists learned that archaeologists are preparing a new suggestion. For this reason, they also started discussing about improvements of their proposal.

What do you think they intend to change?
Can you tell me or draw the possible improvements they intend to make?

If pupils cannot answer, I ask the following questions:
If they tried to find or invent a material to make the net of so that it protects the statue from bumping:
What would they gain and what would they lose from these changes?
Describe how you think they would try their suggestion.
In your opinion, who takes into account the cost and the time needed?

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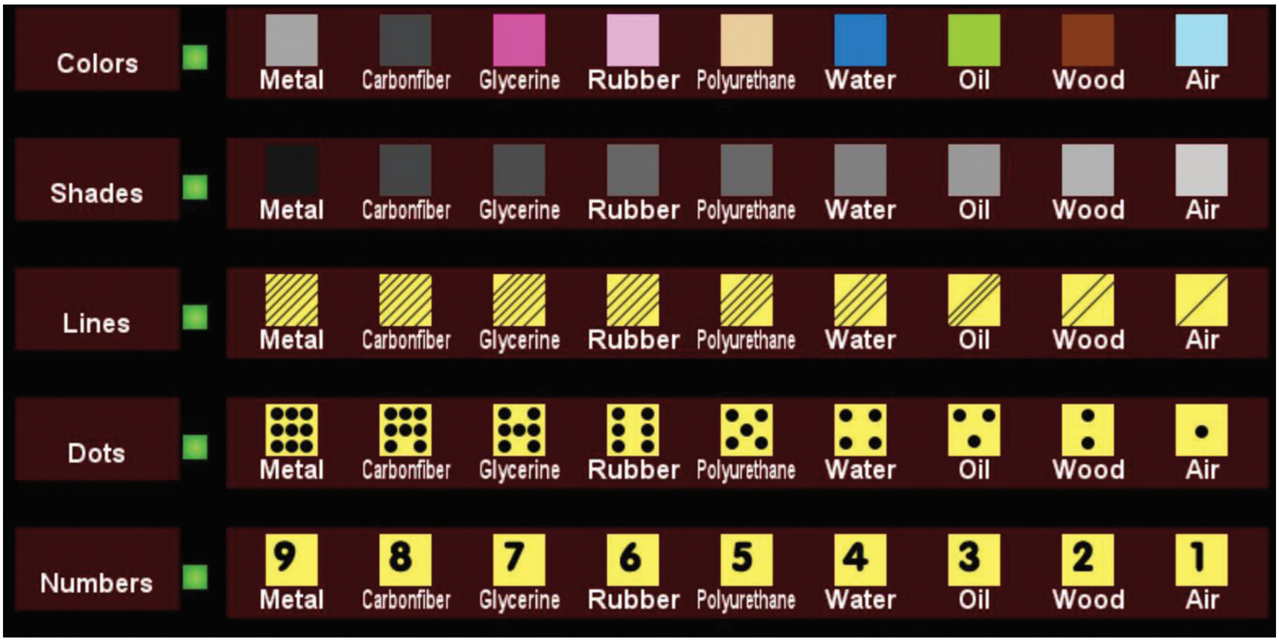
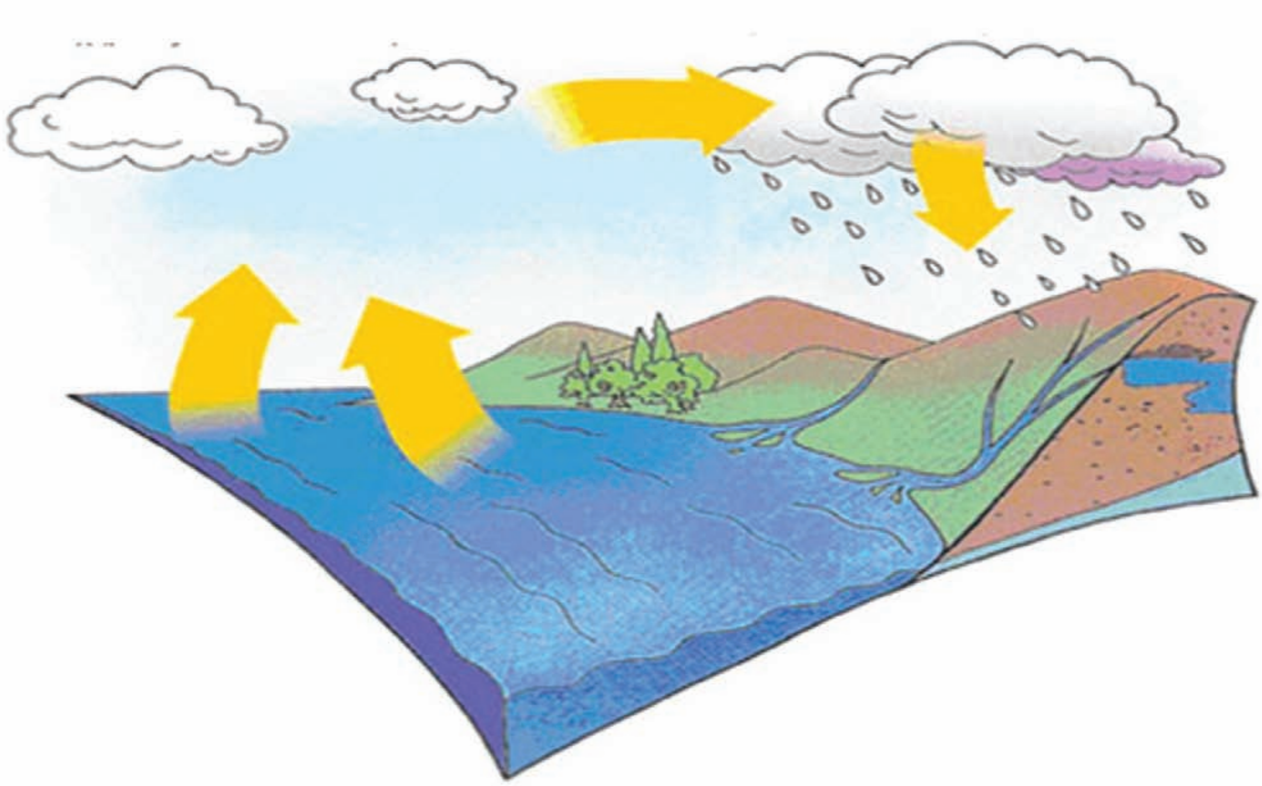


PICTURE 1: SEVERAL MODELS OF DENSITY



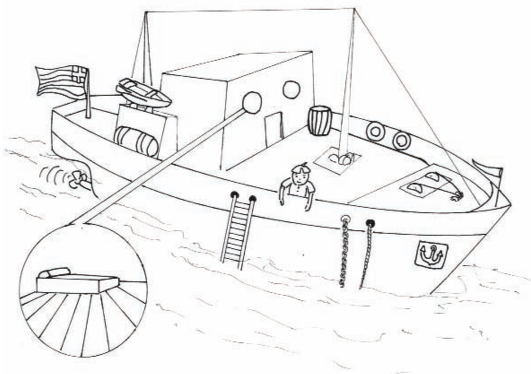
PICTURE 2: MODEL OF THE WATER CYCLE

D: SYNOPSES OF THE LESSONS FOR THE STUDENTS

D: SYNOPSES OF THE LESSONS FOR THE STUDENTS

LESSON 1: FLOATING AND SINKING

Floating and sinking
In the first lesson, we identified that a ship may has on it various objects, such as an anchor, boats, chains, ropes, life boats, a chimney, round life belts, flags, etc. Some of these sink and some others float. The ship itself is a technological object which can float while it sinks under certain and tough conditions.
The steps of variable check

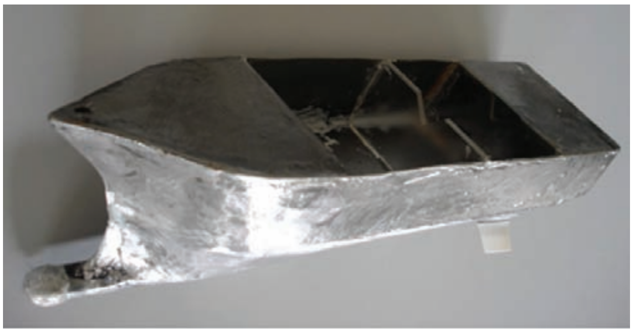


In the first lesson, we wondered which variables influence the floating or sinking of a material. The steps we took to check if a factor (e.g., the weight of a body) influences the floating or sinking of a body in a liquid were:

Steps we followed when we experimented:	(1) We identified the possible variables e.g., the weight or the shape of an object, the kind of a liquid, etc that might influence floating or sinking. (2) We decided how to check if a variable (e.g., the weight of an object) influences the phenomenon or not. For this: • We kept all the other variables **constant**: shape, material, kind of liquid, the width of the vessel. • **We changed** the variable we wanted to check, namely the weight. (3) We made at least two tests so that we could compare the results. (4) We concluded that: • **If** in both tests the object floats, then this variable, that is the weight, does not influence floating. • **If** in both tests the object sinks, then this variable, that is the weight, does not influence sinking. • **If** the object floats in one test and it sinks in the other, then this variable, that is the weight, it influences floating / sinking.

What is a model and how it can be useful?

In the first lesson, we saw and talked about two ship models (a sketch and a metal structure). We agreed that:



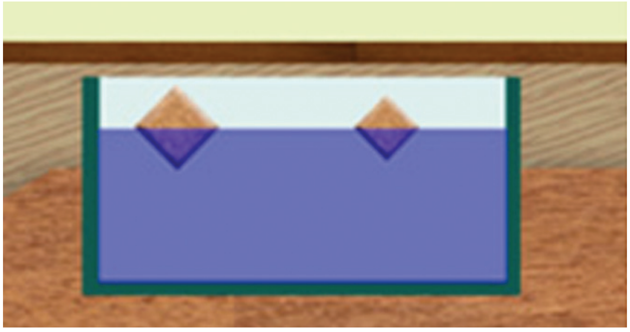
- A ship model and the real one it represents are not identical. It is a representation of a real ship but not an exact replica. This means that a model does not necessarily bear all the information about the ship, e.g., all the objects that exist on a ship.
- What's the usefulness of a ship model It depends on the reason it was made for. For example, the "sketch-model" we saw on the PC is useful because it helps us represent the ship as well as certain objects that exist on it (e.g., an anchor, chains, etc). The "metal ship model" we studied in the first lesson, not only can it represent the interior of the ship (e.g., the ship cabins), but it can help us check if such a structure floats or sinks. Remember that we placed the "metal ship model" in a basin and checked if it floats or sinks.
- A real ship can be represented with more than one model. Each of these usually helps us do something different. For example, we can represent the exterior features of the deck (the stern, the fore, the masts, the chimney) using the ship model in the picture on the right, however we do not have information for its interior. Respectively, when we used the play model in the first lesson we were interested in the ship interior and not the deck.

THE RESULTS AND THE CONCLUSION

Experimental check of variables

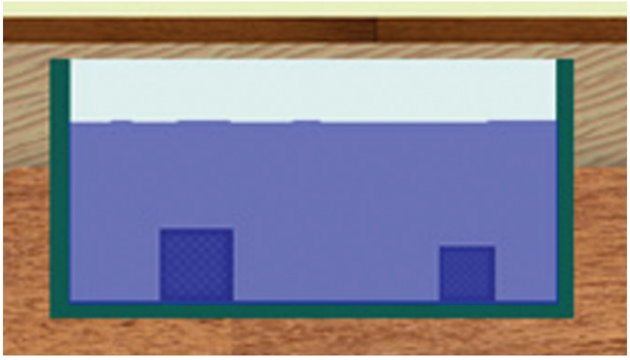
1st Experiment – Floating

On the PC screen, we had a vessel full of water, two objects of cork the same shape and different weight. We observed that while the objects have different weight they float.



2nd Experiment – Sinking

On the PC screen, we had a vessel full of water, two objects of carbon fibber the same shape and different weight. We observed that while the objects have different weight they float.



We concluded that:

The weight of an object does not influence floating or sinking

LESSON 2: FACTORS AFFECTING FLOATING AND SINKING

Floating and sinking
In the first lesson, we started looking into the variables that influence the floating or sinking of a material. We ascertained that the weight of a material does not influence floating or sinking.

The steps of variable check
In the second lesson, we continued looking into the other possible variables that influence floating or sinking. The steps we followed to check if a variable influences the floating or sinking of an object in a liquid were:

Steps we followed when we experimented:	(1) In order to check if a variable influences the phenomenon or not: We kept all the other variables **constant** and **we changed** the variable we wanted to check. (2) We ran at least two tests so that we could compare the results. (3) We concluded that: • **If** the object floats in both tests, then this variable, that is the weight, does not influence floating. • **If** the object sinks in both tests, then this variable, that is the weight, does not influence sinking. • **If** the object floats in one test and it sinks in the other, then this variable, that is the kind of material, influences floating / sinking.

RESULTS AND CONCLUSIONS

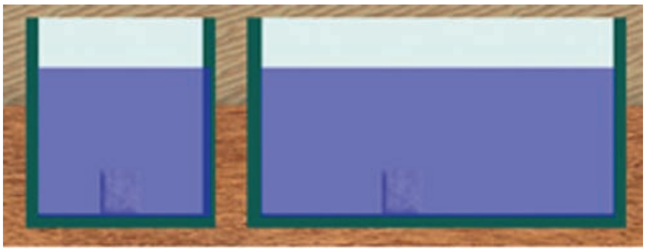
Experimental check of variables

1st Experiment – Floating
In the real lab, we had a narrow and a wide vessel full of water and a piece of wood. We observed that the piece of wood floats both in the narrow and the wide vessel.

We concluded that:
The width of the vessel does not influence the floating of an object

We kept the possible variables constant:
- the kind of the liquid (water)
- he shape of the object (cube)
- the kind of a material (wood)
- the weight of the object

2nd Experiment – Sinking
On the PC screen, we had a narrow and a wide vessel full of water and a marble cube. We observed that the marble cube sinks both in the narrow and the wide vessel.

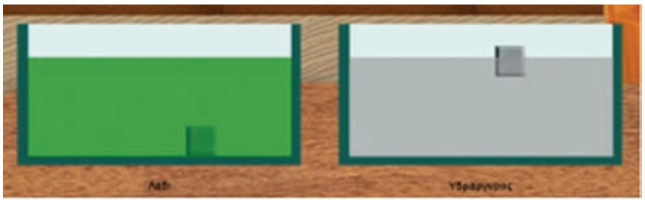


We concluded that:
The width of the vessel does not influence the sinking of an object

We kept the possible variables constant:
- the kind of the liquid (water)
- the shape of the object (cube)
- the kind of the material (marble)
- the weight of the object

3rd Experiment – Floating and sinking

On the PC screen, we had a vessel with oil (left) and a vessel with mercury (right). We observed that the iron cube sinks in oil while it floats in mercury.

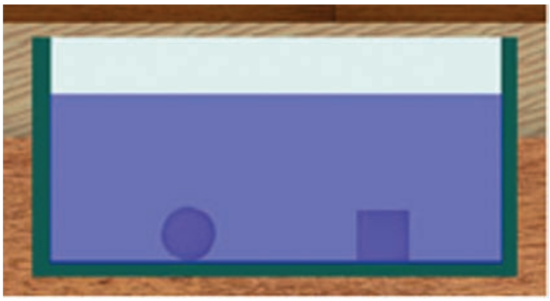


We concluded that:
The kind of a liquid influences the floating or sinking of a material.

We kept the possible variables constant:
- the width of the vessel
- the shape of the object (cube)
- the kind of the material (iron)
- the weight of the body

4th Experiment– Floating and sinking

On the PC screen, we had a vessel full of water, a cube and a rubber sphere. We observed that both the cube and the rubber sphere sink in oil.

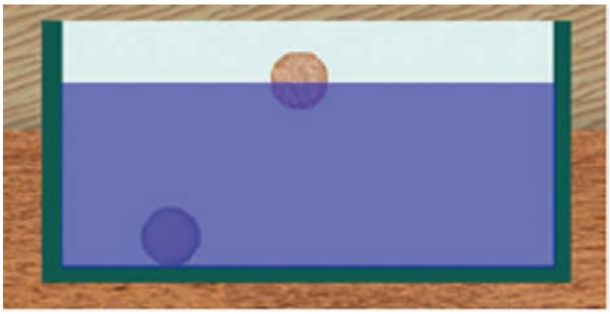


We concluded that:
The shape of a material does not influence floating or sinking.

We kept the possible variables constant:
- the width of the vessel
- the kind of the liquid (water)
- the kind of the material (rubber)
- the weight of the body

5th Experiment– Floating and sinking

On the PC screen, we had a vessel full of water, a rubber sphere and a cork one. We observed that the rubber sphere sinks while the cork one floats.



We concluded that:
The kind of the material influences floating or sinking.

We kept the possible variables constant:
- the width of the vessel
- the kind of the liquid (water)
- the shape of the body

In general, we concluded that:

The floating and sinking of a body depends on:
- the material it is made of, e.g., wood, iron, cork, plastic, etc.
- the kind of the liquid where the material is in, e.g., water, oil, mercury, etc.

and does not depend on:
- the weight of the material
- the width of the vessel
- the shape of the material

LESSON 3: A CRITERION FOR OBJECTS' FLOATING AND SINKING IN WATER

Floating and sinking of materials

In the third lesson, we identified that the little cube of each material has different weight from the other cubes. In order to discern each little cube, we tried to picture them. We noticed that we could picture the little cube of each material in different ways, such as lines, dots, shadows. We agreed to picture the little cube of each material with dots. The heavier the cube is the more dots it will have. For example, we agreed that the iron cube would have 9 dots, while the wooden one would have 2.

Looking for a criterion for floating and sinking

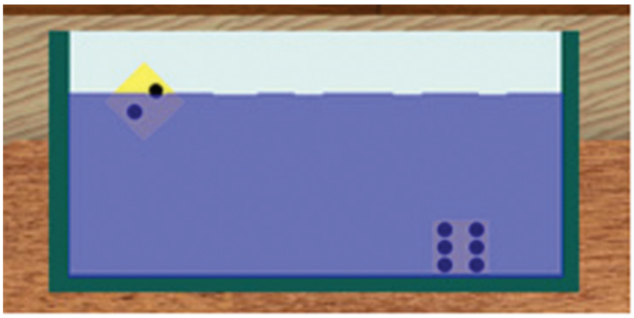
In the process, we looked for a criterion to predict if an object floats or sinks in water.

Experimental activity

On the PC screen, we had a vessel full of water. The little water cube has 4 dots.

We placed a little wooden cube, with 2 dots, in the vessel. We observed that the little wooden cube floats on the water.

Then, we placed a little rubber cube with 6 dots in the vessel. We observed that it sinks in the water.



We concluded that:
When the little cube of the material has fewer dots than the little water cube, it floats.
When the little cube of the material has more dots than the little water cube, it sinks.

LESSON 4: A CRITERION FOR FLOATING AND SINKING IN OTHER LIQUIDS

Floating and Sinking of Materials

In the fourth lesson, we agreed that instead of «dots in the cube» of the material, we would say density of the material. Therefore,

- The more dots the cube of a material has, the bigger its density is.
- The fewer dots the cube of a material has, the smaller its density is.

For example, iron is more dense than wood.

Furthermore, the materials that float on a liquid are less dense than it, while the materials that sink in a liquid are denser than it. For example, we noticed that the **acrylic** cylinder sinks in **glycerine** (green bottle), while it floats in **syrup**. So **acrylic** is denser than **glycerine** and less dense than **syrup**.

Looking for a criterion for floating and sinking

We checked if we could use the density of a material as a criterion to predict if an object floats or sinks in a liquid.

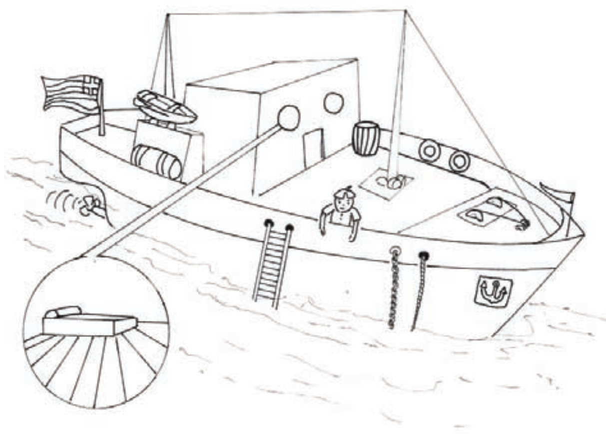
Experimental activity

On the PC screen, we had a vessel with glycerine. The cube of glycerine has 7 dots. We noticed that the wooden sphere, the rubber triangle and the polyurethane's cube float in glycerine because they are less dense than it. Look at their cubes! How many dots are there? Are they fewer or more than the glycerine cube? We also noticed that the iron triangle and the fibber carbon cube sink because they are denser than glycerine.

Synopsis on models

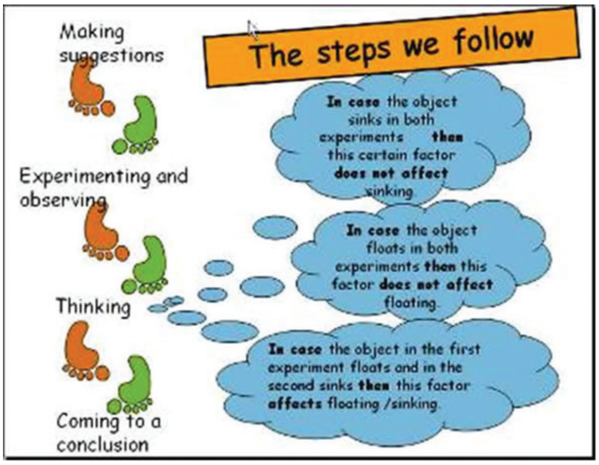
In the previous lessons, we used **various models.** Some of these are:

There was the **model of an object** and more specifically a ship model. One of the ship models we saw was the sketch in the right picture.



There was the model of one property of materials and more specifically the model of density of materials. One of the density models, we used, was the model «cube with dots».

There was the model of a procedure. Specifically, it is the model of the procedure we follow to predict and check if a variable influences a phenomenon, for example, the floating or sinking of a body in a liquid.



In general, we saw that:

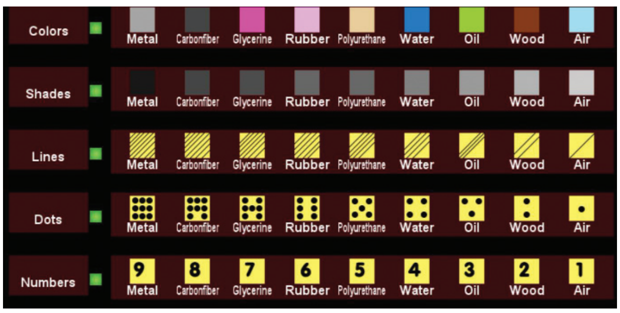
A model is a representation, which does not include all the characteristics of the object it represents. For example, a ship model includes only some of the characteristics of the ship. A second model of the same ship may bear some other characteristics. Why may a model include some characteristics of the ship and exclude some others? It depends on what we aim to do each time with this model.

A model is not an exact replica of reality.

We may use a model to represent, check or predict a phenomenon.

We may have **more than one model** for an object, a property or a procedure. For example, we can see below three different models that represent a ship. Moreover, we can see three different models that represent density using lines, shadows, dots.

SHIP MODELS



MODELS OF THE DENSITY OF MATERIALS

Although there are many models that represent an attribute of the objects, one of them is more useful than the others, depending on the reason we want to use them for. For example, the density model «dots in the cube» is handier than the density model with shadows. That’s because it is easier to count dots and compare densities, instead of compare how dark or light the colour of each cube is. Thus, we are more certain when we predict if a body will float or sink in a liquid.

MATERIALS SCIENCE PROJECT

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