Pupils’ conceptions on the relation between intensive variables and the amount of the system

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Abstract.

In this work we study pupils’ (12 – 15 yrs) conceptions concerning the intensive physical variables. In particular we investigate if pupils relate intensive variables with the amount of the system, which they are referred to. The intensive variables are the density and the pressure in a liquid environment, which were investigated by two written questionnaires (for density and pressure respectively), in a sample of about 300 pupils of the Greek Gymnasium. We are interested about the consistent pupils’ views, which are formed from three similar answers in four tasks, but also for the interpretation of the formation of the inconsistent answers. Our results indicate similarities and also differences in pupils’ answers concerning the two variables, while our hypothesis is verified partly for one out of six pupils. We can distinguish three types / models of consistent reasoning in pupils’ representation, which we call “intensive”, “extensive” and “compressive” types of pupils’ views.

Introduction.

We study pupils’ conceptions concerning the relation between intensive variables (density and pressure) and the amount of the system. That’s why we want to know if this basic formalism of Physics, i.e. the independence of intensive variables from the amount of the system, is also valid for pupils. We decided to study the pairs of quantities: density and weight (mass), as well as the hydrostatic pressure and the weight of the water in order to examine the presence or absence of this relation. The density and pressure quantities have similar definitions: the force is distributed per volume or surface area and they are both used for the interpretation of similar phenomena, e.g. movement or rest of fluids. It is reasonable to expect pupils to describe, predict or interpret similar phenomena in the same way using the concepts of density and pressure.

The Sample and the Questionnaire.

The sample was 306 pupils of the Greek Gymnasium (12 – 15 yrs) for the study of the relation between density and the amount of the system and 312 pupils for the study of the relation between pressure and the amount of the water. The development of the questionnaire was based on a small number of individual, semi-structured interviews given by pupils of the above ages. The final questionnaire for the density as well as for the pressure was distributed in two phases with a month interval between the two phases.

The context of the tasks is that of liquids, as we can change their shape without any change in their volume. The questionnaire on density consists of ten (10) tasks. Four
of the tasks investigate if pupils conserve the two definition quantities of density (two for the weight and two for the volume) during the modification of the shape of the liquids. That’s why, we wonder if pupils could learn the independence of intensive variables from the amount of the system, without knowing the definition of intensive variables as a ratio of two extensive variables. Two of the tasks examine pupils' ability to differentiate weight from volume. The final four tasks ask pupils to compare densities of different quantities of the same liquid, aiming at revealing pupils’ representations concerning density of liquids as an intensive variable.

The questionnaire on pressure consists of eight tasks. Four of them investigate if pupils conserve the two definition quantities of pressure (two for the weight and two for the surface) during the modification of the shape or of the orientation of the liquids. The final four tasks ask pupils to compare pressures of different quantities of the same liquid, aiming at revealing pupils’ representations concerning pressure of liquids as an intensive variable. We did not wonder if pupils differentiate the definition variables of pressure (weight and area), as this case is not met in the literature (Kariotoglou et al., 1990).

Results and Discussion.

We intend to present the results and the discussion of this research for the whole sample, independently of the pupils’ age or preexisting teaching of the relevant phenomena and concepts, because in this phase of our research, we focus on the basic pupils’ reasonings. In the same direction, we don’t have any special interest in the individual responses of pupils per task, but the existence of consistency in pupil’s reasoning. For this purpose the results derive from the comparison of densities and pressures considering that a pupil has consistent view if he/she answers similarly (thought not always correctly) in the three out of four tasks. Aguirre & Erickson (1984) have applied this method for revealing consistent pupils’ views concerning vector characteristics of physical quantities.

The analysis of the questionnaires led us to classify pupils’ consistent conceptions on density and pressure in three types or models, without ignoring the existence of a significant number of inconsistent answers. Some pupils who treat density and/or pressure as an intensive quantity consider that these variables do not depend on the amount of the system (intensive model). Some other pupils who treat density and/or pressure as an extensive quantity consider that these variables depend on the amount of the system, which they are reffered to (extensive model). Still some other pupils, who treat density and/or pressure in a liquid, consider that the liquid is compressible, so that the density or the pressure in a narrow vessel is bigger than in a wide one (compressive model).

One out of six pupils taking part in the investigation has a consistent, “extensive” view for density, as well as for pressure. One out of two pupils for density and one out of five pupils for pressure has a consistent, “intensive” view for these variables. Some pupils approach the “intensive” character of density or pressure using an analog reasoning, which means they understand the studied quantities as a ratio of other variables. In particular for density, some other pupils consider it as a liquid property, in a greater percentage than in the analog approach. These pupils do not recognise the density as a ratio of two extensive variables, but they differentiate density from the weight on the basis of an intuitively captured property. The rest of the pupils, in both questionnaires, give “compressive” or “inconsistent” answers
avoiding the dilemma of intensive / extensive consideration. It seems that these pupils do not understand the non—compressibility of liquids. The latter problem is obvious because in the case of density the relevant views concern the non—conservation of volume, during the shape changes of the liquids.

In the case of pressure the relevant views concern the non-conservation of the surface area during the modification of the shape. We assume that “compressive” or “inconsistent” answers are related to the non-conservation of volume, which is a concept a lot more difficult to be understood by pupils, than the concept of non-conservation of the surface area (Inhelder and Piaget, 1958). As a consequence, we assume that the concept of non-compressibility of liquids is a cognitive obstacle for the understanding of density and pressure as intensive variables.

Conclusions and Implications.

The comparison of pupils’ views and answers between density and pressure could lead us to the conclusion that more pupils consider density as an intensive variable than pressure. This maybe due to pupils ability to capture density, but not pressure, directly as a liquid property, in agreement with the literature (Smith et al., 1986). The last remark could lead us to the didactical re-consideration of the content in order to develop a model appropriate to be taught to a target population, different from the scientific model of Physics. Consequently analyses like the above could contribute in the trace of methods and demands for the didactical negotiation, the learning of facets of the content particularly in the design and development of teaching sequences (Psillos and Kariotoglou 1999) in the frame of an educational reconstruction (Duit 1998). In such an approach it could be important to study pupils’ views according to the pupils’ age and the level of schooling, dealing with the studied phenomena and concepts.

References.