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PARTIALLY POSSIBLE MODELS ON THE CONCEPTS OF FLOTATION AND PRESSURE

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INTRODUCTION

A large part of research on Physics and General Science Education has been mainly focused in determining student's previous ideas or preconceptions (Driver, 1989; Viennot, 1979; McCloskey, 1978). Previous ideas present us a set of notions that the student constructed and which are not only his phenomenological referents but rather cognoscitive constructions that are used as a frame for interpretation for other concepts.

In physics education research, previous ideas on different conceptions have been studied in students of different levels. In particular, the ideas students have about fluids have been focused mainly to the concepts of flotation and pressure. Most of this research has been made considering both concepts independently and limited to some specific activity and phenomenon.

Some of the main conceptions of students that have been found establish relations with only one physical observable. In this manner, for example on flotation concepts relations have been found such as, the dependence only on weight for flotating objects (Inhelder & Piaget, 1972; Hewson, 1985; Autran Von Pfuhl, 1980), the level of sinking depending on the shape of the object (Autran Von Pfuhl,1980), the presence of an ascending force/energy as a property between floating bodies and water (Hewson, 1985), the non-existence of pushing forces when objects are on the surface (Barral, 1990). About pressure there are conceptions such as: air presents two properties, one of exerting a pressure or a thrust and other one of pulling or suctioning liquids, air pushes objects to occupy space (Rollnick & Rutherford, 1990); vacuum exerts pressure or pulls, pressure is conceived as something that pushes or pulls objects (Berg, 1992); gases exert pressure only if they are heated, pushed or are in movement (Seré, 1985); pressure is exerted normally in one direction, downwards and not sideways (Clough & Driver, 1986), etc.

It is interesting to note that these conceptions are dependent on physical context and that student's show a low consistency in the use of these previous ideas (Clough & Driver, 1986). Student's conceptions show a great diversity and the dependence on physical context is showed in different conditions such as in water or air. This does not permit to determine a conceptual model in which the previous ideas are constraining or regulating the students reasoning and with which they construct predictions and explanations. A constricting concept is one that guides or determines a line of inference with other concepts or phenomenological aspects.

The description of students' notions, provide us with sentences or propositions that enable us to understand the interpretation they give to some physical phenomena. Nevertheless this does not permit us to make a representation of how these conceptions are generated and how they are determining the reasoning of students for the interpretation of related phenomena. According to this it becomes necessary to have models with which we can establish the following; they must be able to a) identify students preconceptions; b) establish hierarchies and constricting concepts among students notions; c) identify reasoning processes and d) correlate directly with physical models. The basic conception of possible models within on epistemological approach of the structure of physical theories developed by Sneed (1979) and Stegmueller (1979) will let us determine the principal characteristics of the students construction of they physical explanations.

POSSIBLE MODELS AS STUDENTS CONSTRUCTIONS.

Possible models are dynamics sets that represent main elements in scientific theories (Sneed, 1979). In this sets theory on dynamics or physical theories the formal elements of scientific theory are described in terms of models in two levels. On a first level the phenomenological representation is described mainly by two aspects, the phenomenological sentences (PS) and the correspondence rules (CR). The phenomenological sentences (only of phenomenological terms) and the correspondence rules constitute a nucleus o kernel "K" around which the relations or applications of other physically compatible events will be interpreted. The physical context is denominated as the set "I".

In terms of the sets model, these relationship are described by:

$$\mathbf{Mpp = [K, I]}$$

Theories described by this type of models correspond to functional descriptions; that is to say, they provide us with rules of phenomenological behavior. For example, kinematics, where we have as phenomenological terms and sentences the physical observables, constitute a model of this nature. In this case erroneous ideas or preconceptions are more bounded to reasoning processes (Champagne, Gunstone & Klopfer, 1985; Flores & Gallegos, 1992) than to conceptions such as constructions that permit an explicative or formal causal level of physical phenomena.

It's important to notice that the "Mpp" is not unique and that it depends on the specific relations that the student make between sets "CC" and "RC", in this way there will exist as many partial possible models as relations established by the student. This partially possible models become significant through the necessity of explaining or making predictions so they are not unbounded to an intentional application.

In this paper the possible models are established about the concepts of flotation and pressure, and its relations departing from previous ideas of high school students. An analysis of constricting concepts is also made and some or their implications for education. In the other hand the models of the students are compared with a map of experts to establish some comparisons between them.

To characterize the information available to a high school student in our country on concepts of pressure and flotation an analysis of the most used and teacher recommended physics textbooks was made. In the analysis there were taken as parameters: the structure used to discuss the subject of fluids and the established relations between pressure and flotation. Fourteen books were analyzed, all there were recommended for the pre-college level or for the first two years of college level. Most of these books were written by foreign authors and then translated into Spanish.

METHODOLOGY

INSTRUMENTS

A test was designed for determining constricting concepts and in general preconceptions on pressure and flotation. The test shows the students different phenomenological settings in which the student has to explain explains the causes of the occurrence of an event to take place. The presented settings are intended to establish relations between the two concepts of interest. The test has 14 questions of which 12 represent real and fictitious but possible physical situations, and can be explained through the principles of flotation and pressure. The remaining two questions correspond to the definition of concepts of pressure and to Archimedes' principle. The items included in the test are of three types: 5 are open and they ask to explain the presented situation, 2 of them bear a numerical analysis of direct and inverse proportionality; and 7 are partially open, these are of two types too, those which have a single level of options to select from with accompanying explanations and those which have two levels of selection in which each option of the first level leads to another set of possible selection in the second level. The selection levels must be accompanied of an explanation.

The physical settings of the test questions are focused on problems of pressure and flotation in air and water; settings in which effects of pressure of air and liquids were combined in relation to effects of gases at different pressures in the inside and outside. The relation of pressure with depth was sought in the case of liquids, as well as if such relation showed a dependence between pressure and a privileged direction. Regarding flotation, an explanation was sought based on Archimedes' principle in terms of wether the flotation identified in water or in air. The test included also situations in which relations between flotation and pressure were sought, based on equilibrium between weight and buoyant force.

SUBJECTS

The students were selected from 10 High Schools dependent on the Universidad Nacional Autónoma de México. A total amount of 314 students were evaluated; 173 were catalogue by their teachers as high performers and 141 as low performers. The students were on their last year on this level (sixth grade), some were in the science area and others in humanities area. Also male and female students were included to guarantee an heterogeneous sample.

EXPERTS

Experts made a conceptual map including related concepts of pressure and flotation from which the constricting concepts were determined. This map and the constricting concepts were confronted with the results of the students.

DETERMINATION OF PARTIALLY POSSIBLE MODELS.

The students main conceptual categories were established in terms of frequencies and a distinction was made between phenomenological concepts and theoretical conceptions than can be identified as preconceptions. Through an analysis of the use of those preconceptions the constricting conceptions were determined as well as the correspondence rules.

RESULTS

PARTIALLY POSSIBLE MODELS

As has been said, the test included items on the processes of flotation in air and in liquids to characterize ideas of pressure and flotation in the must general possible way. Also the test looked to determine differences and similitudes between students conceptions when changing context, specifically between gases an liquids. The analysis was made for each item in the test classifying answers in conceptual categories of which only the most frequent ones are shown on table 1. These categories are synthetic propositions corresponding to the arguments elaborated by students in their answers.

Conceptual Categories and Phenomenological Propositions.

Descriptive Categories	
[illegible]	Subject only describes the phenomenological situation
[illegible]	Propositions are incomplete

Conceptual Categories		Conceptual Categories	
[illegible]	A cylinder placed horizontally sinks more than if placed vertically	[illegible]	Pressure acts only horizontally
[illegible]	Object behavior depends on the substance.	[illegible]	Air pushes some objects more than other ones
[illegible]	Pressure is a force	[illegible]	A cylinder sinks to the same level horizontally or vertically
[illegible]	There are different types of pressure	[illegible]	Action of air keeps the duct and glass joined together
[illegible]	Pressure acts on all directions	[illegible]	Flotation is caused by the object's weight
[illegible]	Vacuum attracts or pulls objects	[illegible]	Flotation is caused by the contact geometry of the object
[illegible]	Pressure acts differently in each direction	[illegible]	Flotation is caused by the object's geometry
[illegible]	There is no gravity in vacuum and the weight of objects is caused by the presence of air	[illegible]	Pressure is caused by the body's volume
[illegible]	Object float when submerged by water	[illegible]	The densest liquid stays above the less dense one
[illegible]	The plug pushes air	[illegible]	The less dense liquid stays above the more dense one
[illegible]	Air makes a downward pressure on objects	[illegible]	Vacuum keeps the duct and glass joined together
[illegible]	In vacuum objects do not change their weight	[illegible]	Objects do not change their weight when in water
[illegible]	Trapped air sustains objects	[illegible]	The level of flotation does not change if some of the object's characteristics do not change.
[illegible]	Water makes pressure on objects.	[illegible]	The level of flotation of an object is inversely proportional to some of its properties (mass, weight, shape)
[illegible]	Pressure depends on height (depth)	[illegible]	The level of flotation does not change if objects are of same material
[illegible]	Pressure is located at the bottom of liquids		

TABLE 1. List of principal categories of students.

TABLE 1

A frequencies chart is shown in figure 1 corresponding to the main categories found in students of high and low performance respectively. As can be seen, there are not significative differences between the two levels

(Chi-square = 555.70; df = 528; Contingency Coeff = 0.97656; p = 0.2). This can be due first because the main categories are the same ones and second because the corresponding frequencies are very close.

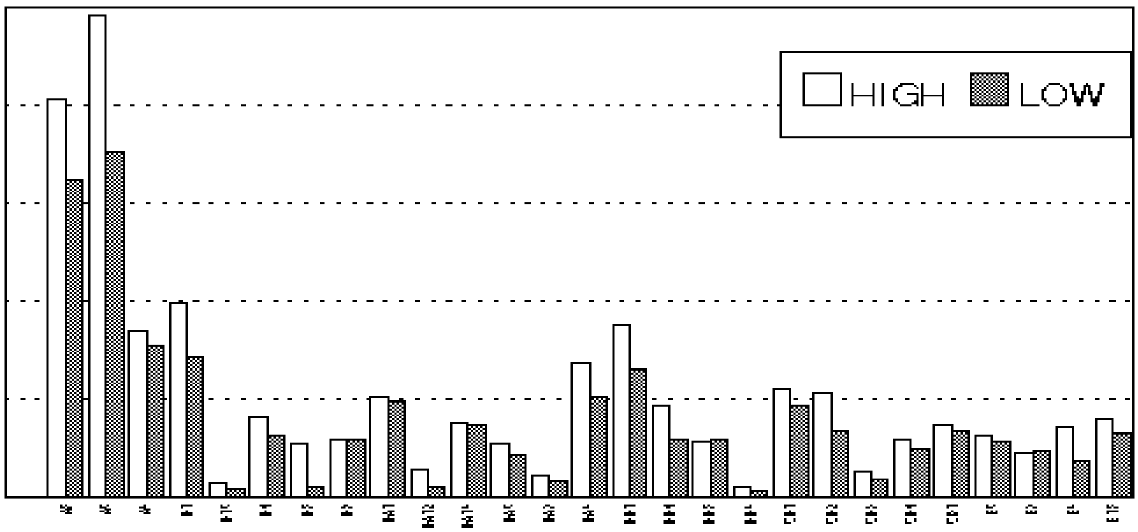

FIGURE 1. CATEGORIES FRECUENCIES' CHART OF THE HIGH AND LOW STUDENTS PERFORMANCE.

FIGURE 1

The partially possible models were constructed after analyzing these main categories in each one of the test items under the following considerations.

a) The models were representations of the conceptual constructions of students about a certain phenomenological process.

b) They are partial models because they do not given account of theoretical aspects, concepts and constructions, only phenomenological ones.

c) They are possible because they characterize not only an idea or set of previous ideas but they show possible inferences that students can establish with this model.

d) The nucleus of the models are made up by sets: PS = phenomenological sentences, they are the descriptions and terms used by students for describing phenomena; CC = constricting conceptions, these are the students previous ideas guiding their inferences, and CR = correspondence rules, they establish the different types of relations that can be established between the phenomenological terms and physical concepts.

In this manner K= [CC, Cr, PS]. With respect to context of particular physical settings in which the model operates is designated by I and in this case is the context: I1 Flotation in liquids, I2 flotation in gases, I3 pressure in liquids and I4 pressure in gases.

Besides establishing these sets, the manner of operationalization between them must be specified, so the possible inferences may be determined. These are of the type AxB---> C This indicates that two operationalized sets, in this case related by logic operators, determine a third set. The students partially possible models are shown in figures 2 to 5.

Partially possible model I_1 = flotation in air

Constricting Concepts CC	Correspondence Rules CR	Phenomenological Sentences PS
CC_1 = There is no gravity in vacuum and the wieght of objects is caused by the presence of air. (BA1) CC_2 = In vacuum objects do not change therir weight (BA12) CC_5 = Object behavior depends on the substance (A8) CC_7 = Pressure is a force (B1)		PS_1 = The objects change their weight in air (question 1) PS_2 = One object change more than other (question 1) PS_3 = Air pushes some objects than other ones (BC) PS_4 = Air makes a downward pressure on objects (BA8)

Operational form: CC x PS -> PS

Partially possible model I_2 = flotation in liquids

Constricting Concepts CC	Correspondence Rules CR	Phenomenological Sentences PS
CC_5 = Object behavior depends on the substance (A8)	RC_{weigth} = Flotation is caused by the objects weight (CB1)	PS_5 = The objects sink more or less than other when their characteristics change
CC_6 = Objects do not change their weight when in water (E6)	RC_{form} = Flotation is a function of object's form (CB2,CB3, CB4)	PS_6 = The object sink more if it's placed vertically or horizontally (A, C)
CC_8 = Water makes pressure on objects (BB1)	$RC_{saturation}$ = Objects float when satured by water (BA6)	PS_7 = The liquid more (or less) dense is over
	$RC_{flotation\ level}$ = The level of flotation change or not in accord with some characteristics of the objects (E7, E15, E8)	
	$RC_{density}$ = Flotation between objects is a function of theirs densities (CD1, CD2)	

Operational form: CC x RC -> PS

Partially possible model I_3 = pressure in air

Constricting Concepts CC	Correspondence Rules CR	Phenomenological Sentences PS
CC3 = The vacuum attracts or pulls objects (CB9) CC6 = TObjects do not change their weight in water (E6) CC8 = Water makes pressure on objects (BB1)		PS_8 = Vacuum keeps the dart and the glass joined together (D) PS_9 = Action of air keeps the dart and glass joined together (C1) PS_{10} = Air makes a downward pressure on objects (BA8) PS_{11} = The object bouyance because has helio

Operational form: CC x PS -> PS

Partially possible model I_4 = pressure in liquid

Constricting Concepts CC	Correspondence Rules CR	Phenomenological Sentences PS
CC7 = Pressure is a force (B1) CC8 = Water makes pressure on objects (BB1)	RC_{height} = Pressure depends on height (BB4, BB5) $RC_{direction}$ = Pressure acts different in each direction (B5, BB8)	PS_{12} = Velocity of water flow is a consequence of presure PS_{13} = Objects are deformated in different directions by pressure PS_{14} = Objects are deformated equal in all directions by pressure PS_{15} = One liquid push to other to change their level

Operational form: CC x RS -> PS

FIGURES 2 TO 5

FLOTATION AND PRESSURE IN EXPERTS AND TEXTBOOKS.

Figure 6 presents the conceptual map made by experts. Its shows the interrelation established between pressure and flotation and the sequence of correspondence rules between phenomenological and theoretical terms.

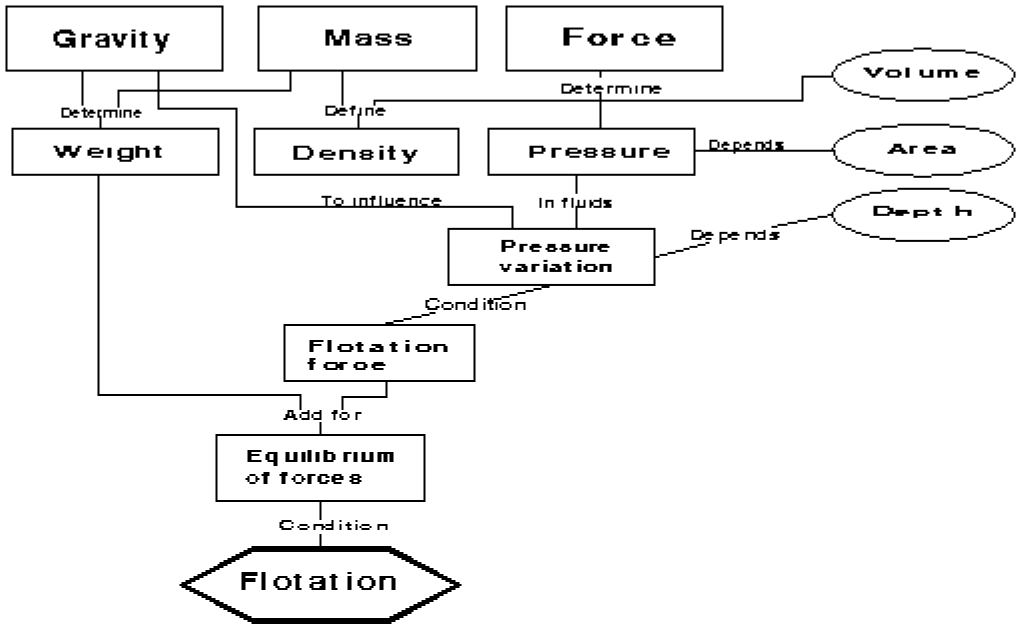

Figure 6. Expert's concept map about flotation and pressure.

FIGURE 6

In this map we notice the presence of terms such as pressure and density appearing as theoretical terms and not as phenomenological ones as is the case with students. It is important to notice how the model is independent from the physical context (liquids or gases) and that it does not recur to specific conceptions as CC categories from students, instead operationalization forms constituted by sum of forces for determining flotation are used.

On the other hand, a brief analysis about the structure of the most used textbooks shows a separation between flotation and the concepts of pressure, as can be observed in students models. It is important to notice that in textbooks there are a few correspondence rules between concepts and phenomenological terms as can be seen in figure 7.

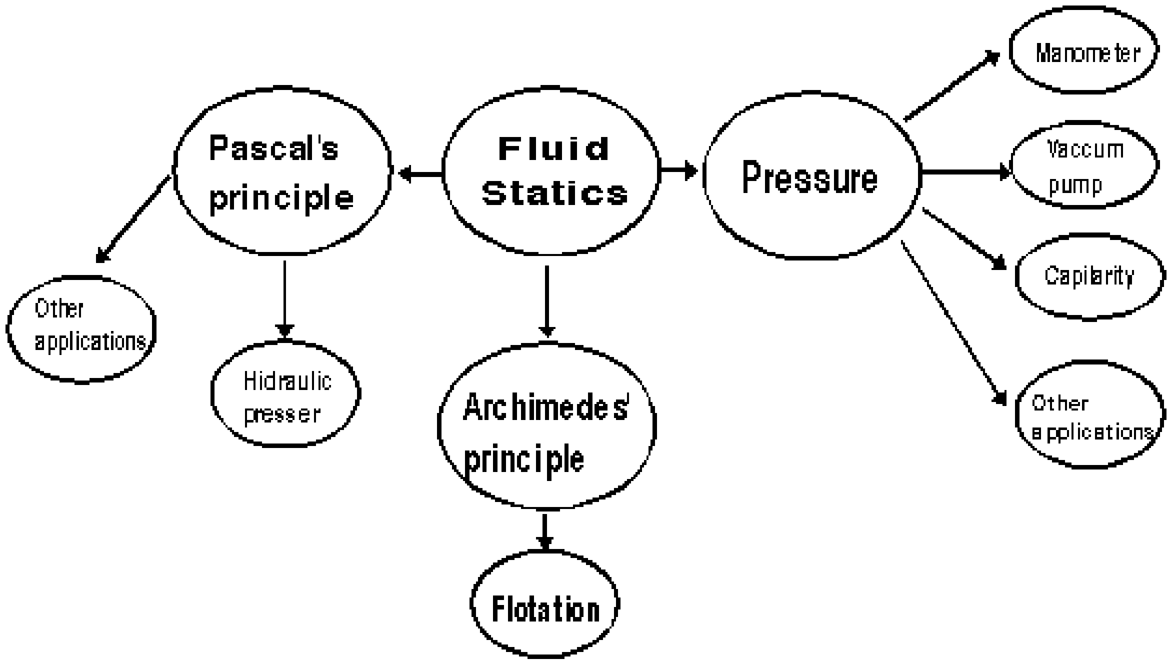

Figure 7. Thematic structure of fluid statics on text's books.

FIGURE 7

CONCLUSIONS.

The Mpp models developed from students conceptions let us make relations between diverse aspects as their previous ideas, their terms and therefore the type of previous phenomenological experiences and also the operational ways with which they establish inferences. Models of this nature give us several advantages.

In the first place, the existence of several models lets us determine the context or phenomenological environment in which these conceptions operate. An especially clear case is the one related to the conception of vacuum. In this case of flotation, the vacuum causes that objects have no properties and then gravity does not manifest itself. Nevertheless when vacuum is related to atmospheric pressure phenomena, it takes properties like those of pulling or pushing objects.

In the second place, with the sets of constricting conceptions and correspondence rules it is possible to generate inferences corresponding to what was stated by the students. For example, in the model of flotation in gases we can generate the inference

CC1 x AC -----> D

"In vacuum there is no gravity, weight depends on air, both change their weight in air, then one will change more than the other".

Sentence as the one above and other combinations with the model sets are found in the subjects' answers.

In third place, models determine the level of formalization and incompleteness of students conceptions and so we can look to a partial conception on flotation rather than a global or totalizing one.

This conception by partial models seems to be reinforced by textbooks that as shown in figure 7, do not integrate flotation in air and in liquids and pressure appears as a separate aspect.

In the comparison of the model of experts represented as a conceptual map with the partial possible models of students, it can be observed that these are lacking, as the textbooks, of an integration of the concepts of pressure and flotation as a consequence of not considering the interaction of forces. Students center their explanations in phenomenological properties or in objects attributes and not in processes as the air, the substance itself of which objects are made of, or a spatial property which determines in a unique way the observed or expected behavior.

This partially possible models indicate us also that subjects not only make use of several models that depend on context, but also at the same time are multivariable, that is they have different possibilities of inference with conceptual sets of each model. This last aspect is especially relevant for education, because it is not a specific set of preconceptions which is to be modified, but a network of possible inferences generated from the students models. This allow us to make a deeper analysis on the structure of theories or scientific models to incorporate elements of structural character and of explicative nature from the scientific models to incorporate then in physics education.

It must be noticed that the partially possible models generated were constructed with the main students categories. The frequencies of categories of incomplete answers and of repeating the test descriptions are very high A5 (365) and A6 (423) which indicates other problems possibly related with a low teaching level and with very partial constructions of the previous ideas of the students.

Finally we will say that in relation to previous ideas and partially possible models of students there are no significative differences between high and low performers. There are other characteristics as the number of contradictions, of incomplete answers, or the use of terms and in general the use of language (not analyzed here), which indicate noticeable differences.

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