

Teaching Physics Concepts

Explanatory Models on Buoyant Force: Results of an Inquiry with University Students

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Abstract

This paper will discuss the results of a research on explanatory models that university students possess about buoyant force. Research in Science Education has contributed to the understanding of students' learning through the modeling of students' reasoning. The idea of "model" as a personal construction has been treated from different theoretical perspectives. We understand that the explanatory model that a student constructs about a physical system could be a key to understand how he uses different ways of reasoning and alternative conceptions in different situations. The identification and characterization of explanatory models could help to understand why students seem to adopt some ideas close to those scientifically accepted in some contexts and, almost simultaneously, work with spontaneous ideas that are incompatible with the scientific ones. The working hypotheses focused on three aspects: students adhere to explanatory models that are related to buoyant force when dealing with problems where bodies are submerged in liquids (H1), there are groups of students that share the same explanatory model (H2), and there are students that selectively activate different explanatory models depending on the problem at hand (H3). As a result of this research, four coherent explanatory models were identified. Non empty sets of students that share each of these models were found. Some students were detected to have elicited different explanatory models in different contexts. These results provide favorable evidence to the stated hypotheses. More over, they are in accordance with previous investigations on the conceptions that students hold and allow to look at them from the explanatory models perspective.

Introduction

This paper presents the analysis of university students' explanatory models about buoyant force. The research stemmed from the need to find out why students seem to adopt ideas that are closer to those scientifically accepted within some contexts while simultaneously using spontaneous conceptions within other contexts.

For many years, research was focused on identifying students' ideas about the world. Students' conceptual difficulties and misunderstandings in learning were described, for example in Hierrezuelo & Montero (1998), and Driver, Squires, Rushworth & Wood-Robinson (1994) among others. Several of these contributions have dealt with the analysis of the general characteristics of the students' naive conceptions. Ausubel stated that the most important factor influencing learning is what the student already knows (Ausubel, Novak, & Hanesian, 1983).

In addition to the identification of these naive ideas, research also focused on studying the "reasoning patterns" (Viennot, 1996). Some of these patterns cannot be associated with specific conceptual fields. For example, she describes the "functional reduction" that students perform when they put aside some variables involved in a concrete problem. Moreover, Viennot (1998) puts forward the notion that students' responses vary according to the context of the problem being analyzed.

Currently, there is a growing concern about answering new questions: Are students' conceptions organized as some kind of structures? If they are, can these structures be

characterized in some way? These questions are currently investigated through different theoretical frameworks among which are those that refer to students' models and modeling.

From the point of view of Physics' epistemology, authors such as Bunge (1985), Estany (1993), Cudmani, Salinas & Jaén (2000) agree in stating that the scientific modeling activity is characterized by the processes of cutting and simplification of the system under study. These processes take place through the disregard of certain intervening factors that are considered irrelevant or negligible in the light of the assumed hypotheses. In other words, intentional simplification and cutting are performed so that the physical system under study can be described through a limited number of variables, that is to say, through a model.

Within the field of Science Education Research, students' models are understood as personal constructions that are described from different theoretical perspectives. Some representatives of these perspectives are, among others: Johnson-Laird (1983) and Holland, Holyoak, Nisbett & Thagard's (1986).

In this paper, we assume that the students construct explanatory models that allow them to explain and predict how a physical system works. These models have an underlying implicit or explicit structure of concepts.

The students' explanatory models often differ from the scientific models. The first ones may include non scientific intuitive ideas as well as some scientific ones. Physicists can use different scientific models to explain a phenomenon depending on their theoretical commitment. This underlying theory is what determines which the relevant variables are and which ones are negligible or can be discarded. Students also select some variables that allow them to describe the physical system. In performing this selection they cut and simplify the problem under study, but usually they don't refer to an explicit model or theory, many times the choice of relevant variables in non intentional and the variables they select are often linked to perceptual characteristics of the system (for example, the body's volume, the amount of liquid in the container).

The resulting explanatory models are dynamic since students seem to construct them on the basis of their interaction with the problem at hand. A change in the context of the physical situation may result in a change of the student's explanatory model. In other words, a student may have a set of coexisting explanatory models for equivalent physical situations and he may activates one or another according to the context of the problem being analyzed. The activation of a certain model might be related to those variables that the student considers relevant for the description of the problem.

The explanatory model about a particular physical system might provide a clue to understanding the way in which students use different types of reasoning and alternative conceptions in different situations. Thus, the hypotheses that guided the present research were:

H1: Faced with problem-solving situations that involve submerged bodies within liquids, students use explanatory models about buoyant force.

H2: There are groups of students who share the same explanatory model.

H3: Students may have different coexisting explanatory models and use one or another depending on the context of the problem at hand.

Methods

The research methodology is described in detail in (Alurralde & Salinas, 2006). It consisted of two stages: the spiraled exploratory inquiry and the hypotheses testing that were carried out through questionnaires and interviews.

First, the whole set of answers given by the total group of students were categorized according to those variables that were considered relevant for the explanation of a physical situation. For example, the answer "The buoyant force depends on the body's volume" was categorized as B3. This category included all those answers that explicitly named the body's volume as a relevant variable for explaining the buoyant force. The answers of each student

were then described as a set of categorized statements. Most of the times, the answers given by a single student were composed by statements that belonged to different categories.

Then, category groupings were defined through the detection of certain category patterns within the explanations given for physical situations. For example, explanations of the buoyant force that were based on the body characteristics and did not consider the liquid as playing any role were clustered in a category group.

Results

Table 1 shows the identified answer categories. Category NA includes answers that were ambiguous, those that were based only on equations, and those of no reply at all.

Table 1: Answer categories

| | |
|----|---|
| A1 | The buoyant force depends on the volume of liquid displaced. |
| B1 | The buoyant force depends on the weight/mass of the body. |
| B2 | The buoyant force depends on the density of the body. |
| B3 | The buoyant force depends on the volume of the body. |
| C1 | The buoyant force increases when depth increases. |
| C2 | The buoyant force depends on pressure. |
| C3 | The buoyant force depends on the density of the liquid. |
| C4 | Student does not discriminate buoyant force/pressure. |
| D | The buoyant force depends on the horizontal surface of body-liquid contact. |
| E1 | In the presence of other forces student does not know how to explain the buoyant force. |
| E2 | The buoyant force does not act or is less when the body is in equilibrium. |
| E3 | The buoyant force depends on the connections. |
| G1 | The buoyant force is greater if the body is higher (degrees of floatability). |
| NA | Non-usable answers. |

The category groupings that were detected were interpreted as indicating the students' commitment to different models:

Scientific Model: comprised by answers consistent with the scientifically accepted model. Those students who seem to be committed to the Scientific Model exclusively use answer categories A1 and C3.

Model 1: The variables considered relevant for buoyant force are those linked exclusively to the submerged body (mass, weight, density, volume). Those students who seem to adhere to Model 1 use answer categories B, but do not use answer categories C (except for C3 which might be used on certain occasions).

Model 2: The variables considered relevant for buoyant force are linked only to the fluid (pressure, depth). The students who seem to adhere to Model 2 use answer categories C, but do not use answer categories B.

Model 3: The higher the body is in the liquid (at lower depth), the stronger the buoyant force is. This model seems to define a "flotation degree" for bodies, associating a stronger buoyant force to bodies that are closer to the surface.

Those students, who present category groupings which are related to the models defined above, were codified as MC, M1, M2 and M3 respectively. Those students who seemed not to be committed to any of the defined models were coded as NM (No Model).

A further analysis of the NM students' answers was performed. This analysis allowed the detection of some students who, under physically equivalent situations, gave different explanations depending on the context of the problem at hand. This behavior could be taken as signaling the presence of question-answer pairs (QA pairs), in accordance with Viennot's proposal (1998) as shown in Table 2.

Table 2. Students' Q-A Type responses

| Type | Alternative explanations | |
|------|---|---|
| QA | For bodies partially submerged, they adhere to Model 1 | For bodies completely submerged, they adhere to Model 2 |
| QA1 | In the absence of connections, they adhere to Model 2. | In the presence of connections, the buoyant force depends on the connections. |
| QA2 | In the absence of connections, they adhere to the model accepted scientifically | In the presence of connections, the buoyant force depends on the connections. |

Table 3 shows the number of students who seem to adhere to each of the proposed models and the number of students who give Q-A type answers. This data were gathered during the hypothesis testing stage. The NI (No Information) Code refers to those students who present 50% or more NA answers.

Table 3. Percentage of students who respond according to models and QA type answers

| Group | | Model / NM | | Model / Q-A Pairs | | Scientific Model/ Non-scientific Model | |
|---------------|----|------------|------|-------------------|-----|--|-----|
| Code | N° | N° | % | N° | % | N° | % |
| MC | 25 | 62 | 73% | 42 | 49% | 25 | 29% |
| M1 | 5 | | | | | 37 | 44% |
| M2 | 5 | | | | | | |
| M3 | 7 | | | | | | |
| PR | 0 | | | | | | |
| PR1 | 5 | | | 20 | 24% | | |
| PR2 | 15 | | | | | | |
| NM | 23 | 23 | 27% | | | | |
| Useful totals | 85 | 85 | 100% | 59 | 73% | 62 | 73% |
| NI | 12 | | | | | | |
| Total | 97 | | | | | | |

Conclusion

Our findings show that it is possible to interpret students' answers as elicitations of different explanatory models. The obtained results are compatible with the first hypothesis (H1), which holds that the students' conceptions are not always a set of isolated notions, but rather notions that can be organized as conceptual structures (explanatory models).

At the different stages of the research, non empty sets of students who seem to adhere to each of those models were found, yielding favorable evidence to the second hypothesis (H2).

The detection of students that give Q-A type answers shows evidence that supports the third assumed hypothesis (H3).

The results obtained in this research not only do agree with the results of former studies on important aspects, but they also show an alternative approach to study students' learning difficulties.

These results suggest that future research is needed in the design and testing of teaching strategies from the theoretical perspective of students' learning adopted here.

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