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THE PROCESS OF TEACHING AND LEARNING PHYSICS - A HISTORY OF ONE LESSON

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Abstract

The ability of designing one's own cognitive activities and providing what it takes to ensure suitable conditions for carrying them out are the foundations for effective achievement of the goals of learning. In author's opinion, appropriately designed and conducted classes of Physics are an excellent occasion for inculcating in students complex and universal skills of designing cognitive activities. The teacher is required to be able to design and conduct classes using methods based on scientists' physics. The aim of this paper is to point out the essence and significance of the designing activities and to present a way of conducting such a lesson by the teacher, a lesson in which focusing on shaping skills in designing cognitive operations to be performed by students, on gaining by them an awareness of the goals and of the ways of performing these activities is clearly apparent.

1 Introduction

1.1 The Problem

How do the students design their own school learning activities? An observation of educational practice leads to a conclusion that the majority of students live "from day today" in their learning, without designing and planning their activities. Usually, the only actions they undertake are the ones that are performed in answer to the requirements coming up from the teachers. It is very rare indeed to come upon persons whose learning habits include gaining and applying design skills or who make strategic and long-term plans. Seldom can we meet students who do conduct a self analysis or an analysis of their operations and the results thus obtained, all in order to consider undertaking any alternatioms that might be necessary and of who organise conditions permitting to achieve their goals. Creating conditions for shaping these skills in students, in a didactics process, is an important mission of education, particularly exhibited in pursuit of developing a learning society and in view of a perspective of learning throughout one's whole life. The mission is not an easy one to realize.

1.2 Assumptions

Complex skills of designing ones own activities, particularly a cognitive activity, have to be acquired and constantly improved. The responsibility of every teacher is to help students in shaping and refining such skills.

The aim of this paper is to present the possibilities and conditions which can be created at classes of physics, in order to shape in students skills of designing and applying cognitive operations. As an introduction, it is necessary to make few general comments concerning designing such lessons by the teacher and formulating assumptions on the process of learning.

The process of learning is a sequence of cyclically repeated distinctive, design, preparation, application, research-directed and improvement operations. That is why the teacher's design procedure may be split into designing a strategy, the stages and current designing. The project of strategy contains the total time period of conducting a didactics-and-educational process and includes assumptions concerning the system and structure of all actions undertaken by the students and by the teacher. It also specifies what are the goals of their activities and ways, stages and methods of achieving these goals. The basic rule in the process of teacher's design procedures is the rule of conforming detailed didactics' solutions to assumptions formulated in the project of strategy. It is impossible to present all of the assumptions in a short paper. I therefore shall limit myself to indicate just two of the assumptions that I adopt to define the way of conducting operations by the students and the teacher, in the proposed strategy:

- The cognitive operations conducted by the students ought to imitate scientists' physics [1] (to the maximum possible extent)
- The operations conducted by the teacher in the process of teaching ought to be performed in accordance with the rules of a didactics-and-research model that enables performing creative and dynamic operations both by the students and by the teacher [2].

From an analysis of cognitive processes of a human being and from educational practice it follows that creating conditions for initiating a natural course of cognitive processes and directing it in accordance with a hopefully, perfect model resembles the scientists' physics. This is an optimum way of teaching physics in pursuit of extensive development of students and in pursuit of shaping in them subjective competence and general competence.

I then accept an assumption that the activity of students will be divided into five activity stages which reflect scientists' physics characteristic stages and expose situations and operations important for achieving educational goals. That is why, interactions of a methodological character play an essential role in teacher's interactions aiming at aiding and directing the work of students.

2 A History of One Lesson

In order to justify a thesis that teaching physics in a way resembling scientists' physics may be a very good occasion for shaping skills in designing cognitive activities, I shall present a history of conducting one lesson in junior high school, a lesson which was dedicated to the buoyant force and Archimedes Principle. According to the accepted assumptions, the lesson was composed of five stages. A description at the beginning of each stage contains its assumptions and characteristic features.

2.1 Stage One - The Initial Situation

Stage One is a stage of observing, sensing and trying to undertake actions in situations in which it is necessary to get acquainted with, create and transform an isolated part of either a natural reality or a reality created by the activity of a human being. This is the stage of "entering" into defined situations, from which it results that it is necessary and important to undertake a cognitive operation. For the sake of this stage, the teacher must design a way of arranging the initial situation, so as to introduce the students into the issues of the problem, simultaneously engaging them emotionally and provoking to ask questions. It is a good thing if the situations are important, interesting or surprising to the students. Demonstration, experiment, presentation, film, picture, drawing, a suitable plot, these all are the means of arranging a didactics' situation

From lesson: A big transparent vessel appears on the table.

The teacher: "Let us imagine that the weather is beautiful and sunny, we are at a riverside, we have got a boat (he places a flat vessel on the water) and we set our hearts to use the boat to get over to the other side, to land on a beautiful island visible from afar. Let us assume that there are 6 of us (he places 6 weights in the boat, the weights which play the role of models of the members of the crew). And what do we see? The boat sinks. What do we do? Luckily, the water is shallow near the shore." Here the students most frequently suggest placing the passengers in the boat more evenly or to transport first a part of them to the island and then, come back for the rest. The teacher declares that nobody wants to stay at the shore; they all want to row together. He pours out the water and, according to students' suggestions, tries to evenly distribute the weights in the boat. The subsequent trial ends up with sinking of the boat once again. Usually, the students give no more new suggestions.

The teacher suggests: "Why don't we swim to the island, partly immersed in the water, since we already are wet? The boys, for example, shall grab hold of the board, leaving their bodies under water and the girls in the boat shall row." And he fastens three weights under the water (stressing that of course, they shall leave their heads above the surface of the water). In every experienced situation, this suggestion, this fragment of arrangement of the initial situation, evoked amusement in the class. It turns out that this way of presenting the situation becomes a, so called, "memory hook" to the students, for everything that is the subject of work during this lesson. The teacher fastens the weights to the boat and once again, he places the whole arrangement in the water. "And what do we observe? This time our boat does not sink. Why?" Most frequently, the students are very surprised by such an outcome. "Yes why, we did not decrease the number of our passengers, nor did they lose weight, in meantime!" This is the right timing for the teacher to tell the students of the possibilities of transporting large and heavy freights by means of rafts, if they are fastened to the rafts under the water and of the history of Mr. Zabłocki who transported soap under a hull of a ship (this is the genesis of a popular Polish saying, "To end up as Mr. Zabłocki on soap", meaning in English, "To make a bad deal"). "Why, when the weight is inside the boat (once again, he places, this time a metal block in the vessel), the boat sinks and when it is underneath the boat (he removes the block from the boat and fastens it underneath), it does not?"

Such an arrangement of the initial situation results in that the students, intrigued by the problem, try to find an explanation. And they should be given a chance (time and freedom of discussion) to undertake attempts of additional, practical actions and attempts of explaining them. An initial analysis of the problem, performed by the students and attempts of practical actions, usually do not lead to correct solutions. Yet they induce a feeling of deficiency and a will for undertaking further actions. More than often, the students try to explain that maintaining buoyancy is caused by a reduction of the weight of the baggage. But in return to the teacher's comment, "But since the mass of the baggage remains undiminished, how is it possible for the weight to be diminished?", a consternation follows. The students realise at this very moment that they lack knowledge and skills to answer questions that spring up. Here is the situation that forces a cognitive problem to be specified correctly. For this reason, appropriate comments of the teacher are very important.

The teacher: "People kept asking questions on the buoyancy of bodies in the context of various of their needs (for example, transporting goods by waterways, analysing the density of solid and liquid bodies in the context of buoyancy, curiosity accompnying buoyancy of the human body). Searching for answers brought about a discovery of the buoyant force and deriving a description on what and how it is dependent from it. The acquired knowledge on how the fluids act on bodies submerged in them, allowed for numerous applications. Enormous ships transporting thousands of tons of cargo, submarines or the exploration of the underwater world and also constructions of balloons and airships are the proof of that. Sensing the existence of a practical necessity, a feeling of encountering difficulties on the way to satisfy this necessity, engagement, analysing the whole situation, realising what we already know, in view of we do not, allows us to precisely formulate the cognitive problem. The way from a practical problem to a cognitive problem is often a way leading to new research operations, to new discoveries."

The students who for the first time encounter this method of conducting a lesson, are usually surprised that lack of supplying answers by them and their inability to cope with the problem of how to explain the observed facts is nothing to be ashamed of and not a reason for humiliation but means of conscious application of a cognitive process. Sensing and specifying what knowledge we are missing (for example, we do not know exactly how does this phenomenon proceed, how to describe it quantitatively, what are the dependences between defined physical quantities describing a given phenomenon and so on) is an impulse to try to specify a cognitive problem and to decide on how to solve it (because it is worth it, because it is important, interesting, necessary, useful, valuable, helpful etc.).

2.2 Stage Two - An Extended Analysis of the Initial Situation

The students now know[1] that at this stage, they shall carry out an extended analysis of the situation from Stage One and of similar

[1] They already know that they are being teached using such a method. If students are not yet introduced into this method, the teacher explains what procedures must be performed in each stage.

situations, in this case, connected with floating and sinking of different bodies (both in liquids and in gases, that is, in fluids), shall describe the goals in detail and shall plan the cognitive procedure in a way modelled after scientists' physics. They know that analysing situations and comparing them leads to expracting features that are essential to these situations and to synthesising these features and generalising them. They shall create a model of these situations, formulate the aim of further cognitive operations and plan a way of conducting them.

The teacher displays a slide coming from a previously prepared multimedia presentation including photos depicting: a man lying on the water and reading a newspaper (in the Dead Sea), a ship, a stone lying on the sea floor, a submarine, a diver, a fish, a balloon floating in the air.

The teacher: "Why do some bodies in some conditions float in the air, on the surface of the water, in the water and others sink, fall? In a very salty Dead Sea, people can lie down on the water and read a newspaper, a big ship floats in the water and a small stone sinks. Submarines, divers and fish may float at chosen debts. Similarly, balloons may float in the air at chosen altitudes. Our situation of the boat sinking with the block inside it and floating, when the block is hooked underneath the vessel, is similar to the situations described above. If we cannot explain an observed situation, it means that we are either lacking knowledge in a given area of reality or the ability to explain, since explanation is always referring to a certain principle, model, theory. An analysis and a comparison of these situations is the beginning of gaining knowledge on these situations. Please compare these situations and try to grasp, we say, extraxt features that are essential and mutual for all these situations. Omitting unimportant features and accepting simplifying assumptions concerning the analysed situations and areas of reality is an essential element of the cognitive process. It is called modelling. In a specific situation, we try to create a simplified image of the analysed reality of interest, the image being so much consistent with this reality as to be used as a tool for explaining, forecasting and performing projects of practical activities in this reality."

Not only methodological information is important in teacher's interactions consisting of aiding and directing the work of students, but also some motivating comments.

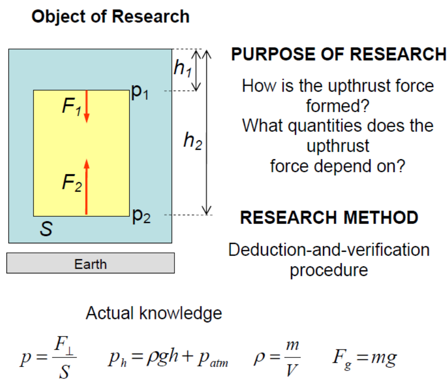
The teacher: “While we are modelling an area of reality that is of interest to us, we may sometimes discard something that we think is unimportant, from our point of view and what may turn out later on, important from another point of view. Thanks to some other attitude towards this issue, we may discover something interesting and important. The history of physics knows many such examples. Who knows, may be the world around us would look totally different if somebody did not notice that a magnetic needle located near a conductor deflected, each time that electric current begun to flow. Another example, what extremely useful consequences came from an observation that growing naturally, thistle fruiting bodies (used as stickers by playing children), may become an object of imitation. And now, Velcro® fasteners are commonly being used for fastening shoes, clothes, handbags and even space suits. No one knows whether somebody in the near future will not make an observation and notice something who no one else before noticed. It is a good thing to train in ourselves an ability of exquisite observation and analysing the surrounding reality. It is a very useful capability in every domain of the reality.”

“Coming back to our situations, please do analyse them, compare their features and try to extract these features of reality that are mutual and essential in these situations. Create a model of this area of reality”.

The students commence their work, drawing sketches in their notebooks. They are accustomed to undertaking unaided trials of various activities, including the ones in writing. This is a characteristic element of the described method. The teacher looks into their notebooks in meantime. They are accustomed to this, because they know why is he doing it and they are not afraid to disclose their eventual mistakes. For the teacher, this is a possibility of quickly collecting and what is very important, from all the students in the class, the current data on the course of the students’ work and on the results they obtain therein (the teacher’s current research procedure). The teacher, seeing what are the ideas presented by individual students, what difficulties do they encounter, what is not a problem to them, how many of the students can handle it, how many cannot, who are these students, how fast do they work, and so on, has the opportunity of undertaking current decisions on interactions directing individual students, as well as the whole class. The assumption is to give everybody a chance to attain the goal unaided. The teacher in pursuit of helps, first proceeding to such actions that would not deprive the student of a possibility of achieving the success all by himself. The students work alone but if they want to verbalise their thoughts, they have a chance. They may communicate with the neighbours, speak up on the forum of the class, since the possibility of discussing one's own ideas is one of the conditions of a creative processes. A phase of unaided work is followed by a discussion of the effects. The students announce that in all of these situations, we are dealing with a certain object immersed in a fluid medium (water, air) and it is the interactions exerted on the object by the medium that are vital, from the point of view of the effects that are of interest to us. And since everything is subjected to the field of gravity, the Earth is acting as well. We therefore are interested in the state of equilibrium. The students notice that even if they know what is the magnitude of the terrestrial gravity force, they do not know what is the magnitude of the counteracting force of the medium, which in some situations is capable of compensating the terrestrial gravity force. So, they formulate a question on an upthrusting force counteracting the gravity force. They suggest poising the following questions: Where does the upthrust force come from? What quantities does it depend on and how? Next, they approach designing a method for obtaining the answer, thus formulating hypotheses concerning the upthrust force. They analyse interactions exerted on all of the surfaces of the submerged bodies and plan a way to obtain some sort of dependence expressing the resultant force acting on a body submerged in liquid. They also determine what knowledge they will need, in order to accomplish that (concerning pressure, hydrostatic pressure and Pascal's Principle).

The teacher, making use of all of the information gathered in the course of this stage and on the results of students' work, arranges the information in order, provides aid and directs the diligence of students, leading to the assumed final results of Stage Two. This is one of a number of important functions performed by the teacher, in each of the stages.

The teacher sums up the submitted students' ideas and resorts to a presentation. Each element of the illustration appears on the screen, accompanied by an appropriate comment.



The teacher,"In all of the analysed situations, all of the objects which are of interest to us, are either partly or totally immersed in fluids (a balloon is a body immersed in gas). Both the immersed objects and the medium remain in the gravitational field. In order to simplify the problem, we may assume that these real-life objects can be modelled by a cylinder. What is of interest to us in these situations? I remind you that we want to explain why some objects do sink and others float in equilibrium in fluids or on the surface of fluid, only partly immersed. From a practical point of view, we are interested in the equilibrium of these objects, they may not sink or fall down to the earth. When will the object be in equilibrium? What are the interactions that an object immersed in fluid is subjected to? You say that in order to prevent the sinking of a ship, the interaction of liquid must be substantially big. How big? The quantative dependences are important, since only resorting to them can we construct, foresee, explain. From what and how does the interaction of liquids depend on objects immersed in them? What method shall we use searching for answers to subsequent questions? I shall give you a clue: we shall follow a way that is a deduction-and-verification procedure known in physics as "operating with a model". We shall define all forces acting on an object immersed in liquid (gravitational force and a force originating from the liquid and acting on all of the surfaces of our model object). Next, we shall sum up these forces. Basing on the possessed knowledge (on equilibrium, forces, pressure, hydrostatic pressure, Pascal's Principle), we shall come up to an equation depicting the resultant force acting on a body immersed in liquid. The derived dependence will only be a hypothesis (justified by a presumption) that would have to be subjected to experimental checking (empiric verification). So there are three tasks for us to fulfil: formulate a hypothesis, work out an experimental method of checking it and carry out the experiments allowing us either to confirm (or discard) the hypothesis."

2.3 Stage Three - Implementing Cognitive Tasks

This stage is dedicated to implementing the planned cognitive tasks, taking into consideration specific standards and the rules of scientists' physics. Depending on the cognitive advancement of students and their progress in thorough studies of physics, different rational and empiric strategies are implemented, based on deductive inference or on a nondeductive inference. At te age of about 12, that is, at the level of junior high school (in individual cases, somewhat earlier or later), the students are capable of implementing deduction-andverification procedures. If the students who we work with possess substantial knowledge, we may propose that they follow a procedure of that type.

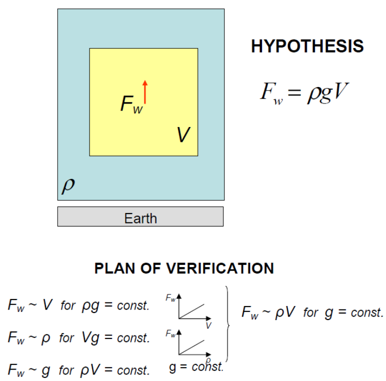
According to the plan, the students carry on analysing forces acting on the surfaces of the cubicoid and derive an expression on the resultant force acting on a body immersed in liquid. The students make drawings and perform calculations in their notebooks. The teacher monitors the course and results of their work and passes feedback information to them, reminds them of settlements written down in the mutually prepared, research project.

Similarly as in every stage, here too, following an unaided part of students' work, the teacher helps them to gather and arrange in order the results of the work. His activities simultaneously include supplying procedure and result models to students who nor did they manage to formulate a hypothesis unaided nor using individual help from the teacher. The teacher sums up and if necessary, explains particular stages of reasoning referring to a previously prepared animation, since drawing and writing on the blackboard lasts too long, is wearing and taken by students as unnecessary repeating operations that were already accomplished. An additional advantage of the presentation is that it can be handed over to the students for copying, as a note from the lesson (that they can complement it), convenient in case of reviews.

The teacher: "In the analysis of interactions on an object submerged in liquids (in order to simplify things we assume that the object has a regular shape), we ask what is it that acts on that object. There are two sources of such actions: the Earth and liquid. If we know the mass of the liquid, we shall be able to calculate the gravity force of the Earth. The liquid acts on the walls of the object from all of its surfaces. From the previous lessons we know that at a certain depth, the hydrostatic pressure amounts to ρgh plus the magnitude of the atmospheric pressure (from Pascal's Principle). The summed up force acting on all of the surfaces is equal to zero, so only the top and the bottom surfaces of our cylinder have to be taken into consideration in our analysis. We guess that the difference between these forces will give us the resultant force directed upward, that is, the sought-after upthrust force. So, we calculate the force and we can do it, since we already have the knowledge indispensable for that. There is a column of water of a height h_1 found over the top surface of our cylinder, thus the pressure p_1 equals to $\rho gh_1 + p_{\text{atm}}$. Out of the definition of pressure (the magnitude of force perpendicular to the surface, divided by the magnitude of the area of surface), we derive the magnitude of the force, with which the liquid acts on the top surface of the cylinder. This force amounts to $F_1 = \rho gh_1 S + p_{\text{atm}}$. Analogically, we find that the magnitude of force F_2 acting on the bottom surface of the cylinder (also of area S) equals to $\rho gh_2 S + p_{\text{atm}}$. The difference between these two gives us the magnitude of the resultant force, correctly named, the upthrust force (it is directed upwards, towards the surface of liquid. We obtain $F_w = \rho gS(h_2 - h_1) = \rho gV$, where V is the volume of the immerse body. Now, it is easy to notice that the volume of the submerged body equals to the volume of the displaced liquid, so take a note that the place of liquid is now occupied by the cylinder which had to displace the same amount of water it itself occupies (for the majority of students it will be obvious if you comment it). Let us continue our calculations. We may now write down the equation on the resultant force as: $F_w = \rho gV$, where V is this time, the volume of displaced liquid (by a submerged body) and from the definition of the density of a fluid ($\rho = m/V$), we obtain the equation describing the upthrust force under the form of: $F_w = mg$, where m is the mass of the displaced liquid. This means that the magnitude of the upthrust force equals to the weight of the displaced liquid. This dependence is called the Archimedes Principle."

The teacher now reminds the students that dependences obtained using the argumentation (and the assumed model) from the point of view of scientists' physics constitute a hypotheses. They have to be submitted to experimental verification. Only on passing such verification can they be accepted and included in the system of knowledge on hydrostatics.

The students now commence to design methods of verification, the procedure and apparatus, methods of measurement and directions for processing the measured results. They work the same way as in previous stages (notebooks). At the end of this stage, the teacher displays a consecutive slide "the hypothesis and the method of its verification", summing up and reinforcing the effects of the students' work. Together with the students, he comments and particularises his standpoint of verifying the magnitude of the upthrust force in dependence on the variables appearing in this dependence.



The teacher: "We assume that g is a constant quantity (everything takes place at a given point of the field). That is why, in order to verify the formulated hypothesis, we have to find out how does the upthrust force depend on the volume of the immersed part of the body) at a uniform density) and how does it depend on the density of liquid, at a fixed depth of immersion. We expect to obtain a linear dependence (the diagrams are on the slide). How many measuring points should we have? We plan minimum 4 measuring points for the verification of each part of the hypothesis. So, what do we have to prepare? The assumptions indicate a necessity to prepare four liquids of different densities (it may be water without salt and water of various degrees of salinity) and four cylinders (or other solids) of various volumes. We may also use one cylinder and immerse it gradually, calculating the immersed volume (from the equation on the volume of a cylinder). The upthrust force may be calculated as the difference between a reading of a force gauge, on which the cylinder is hung when it is in air and the reading of the force gauge, when the cylinder is be immersed in liquid."

When it comes to a practical realisation of the verification procedure in this class, the teacher, together with the students decided to reschedule the experimental operations to the classes of the physics interest group. Yet he did not resign from designing these operations, since it is necessary that a complete structure of cognitive operations take root in students' minds. It is understandable in this context that many a teacher dreams of well-equipped physics laboratories, a chance to conduct physics classes in groups, a sufficient number of class hours and a chance to carry out physics classes in two-hour blocks.

2.4 Stage Four - A Synthesis of Cognitive Results

This stage is dedicated to synthesising and arranging the cognitive effects, that is, the beliefs and knowledge on the given area of the physical reality, the methods of its research, creation and transformation. A note is taken down, which reflects the most vital results obtained in the first three cognitive stages. In a situation of acquiring a substantial self-reliance in learning physics according to this model, the students are capable of performing the synthesis, arranging in order the cognitive results and writing down the note (sometimes, with a little help from the teacher). Creating and putting to order ones own experience acquired at the time of cognitive and practical activities in subsequent stages and analysing the obtained results turns out to be very important for effective learning in every area of activity of a human being.

Here too, for the sake of the synthesis, the teacher uses the previously prepared presentation. Once again, he displays the slide containing situations, which were the subject of analyses (due to specific practical problems that is, sinking, floating), the model situation, cognitive problems, the applied method of their solution and a method of approaching the solution.

A worthwhile method of helping students is to make multimedia presentations prepared by the teacher available to the students. It may be a students' version for creative completion. Later on, they may create own studies of successive problems of physics.

The teacher also throws in his own comment (or reminds), "The knowledge on the physical reality and the methods of its research is a structure composed of a data base containing a set of information originating from observation and experiments, concepts and rules of a language accepted for describing this reality, principles ensuing from generalising empiric data, assumptions, models, theories, and hypotheses. The characteristic feature of physical knowledge on natural reality is a systematic approach resulting from the following two facts. First, the physical knowledge on reality is its reflection, that is, a reflection of a systematic character of reality. It is ruled by a defined order, there exist objects of defined characteristics, defined structure of laws and principles describing relations between these objects, their characteristics and changes occurring in these characteristics. This systematic character of reality manifests itself with the possibility of describing it with a defined number of simple concepts and simple and common laws, principles, models and theories.

Second, the system of knowledge is a consequence of developed cognitive operations' principles, assumed methods of research and methods of building it up. It is the consequence methodological principles that are compulsory in research practice.

Both of the factors, intermingling with each other, decide on the fact that the knowledge on the reality and on its research demonstrates the features of a system, in a sense given to it in natural sciences. Physicians express their opinion on the systematic reality of physics by driving towards a great unification of theories, towards describing all known interactions in the frame of one theory. The characteristic feature of the system of knowledge and of the methods of physics, which cannot be forgotten in the process of research and also at our classes of physics, that every principle, model, theory, each sentence expressing a physical reality is formulated and spoken in the context of the way that lead its formulation and may be interpreted and used only in the context of this way (thus, in the context of assumptions and of the procedure of cognitive operations, apparatus used and methods of processing and interpreting the cognitive results). In science, in approaching the truth about Nature, in applications, we cannot use the cognitive results, if we will not state the assumptions and research procedures."

It appears that the students accept these comments with understanding. In view of the work they have accomplished, such a comment makes their activities assume an air of importance. Along with subsequent, consequently repeated operation procedures concerning subsequent areas of physical reality, they demonstrate an ever growing level of understanding.

2.5 Stage Five - Applications

This stage includes utilising the acquired knowledge in specific practical situations. This is an integral part of the whole cognitive structure. A series of situations requiring the use of this knowledge and methods ought to make the learners appreciate the value of completed tasks and of the acquired knowledge and skills, and also to upgrade the level of their selfassessment.

As an introduction to this stage, the teacher either submits for an analysis a situation with a problem requiring the use of knowledge or asks to remind him, "What are the situations requiring the use of knowledge (also the use of methods) and what does the process of using knowledge consist of?" He sums up the students comments, putting stress on the correct ones. "The situations requiring the use of knowledge and of methods is the ones, in which, for example, it is necessary to diagnose and explain the observed states, phenomena, processes or characteristics of the chosen areas and elements of reality. These are also situations, in which it is necessary to either predict (forecast) changes or design and implement new method or solution and situations requiring creation of new areas of reality or modifying the existing ones."

Next, the students make use of the knowledge acquired during the lesson, in order to explain the surprising effects observed at the beginning of the lesson. The students explain why the boat remained floating on the surface of the water, when the weights were tied up outside the board and were immersed, but it sunk when the weights were inside the boat. Next, they use the acquired knowledge to analyse the remaining situations, the situations which were analysed only initially in the Second Stage of the lesson. Repeated use of the acquired elements of knowledge (at a given and subsequent lesson and performed independently as homework) is an indispensable condition of "building it" into their own individual system of knowledge on the surrounding reality.

3 Conclusions

The course of the lesson indicates that in school conditions, the students are able to implement design operations effectively[2]. Acquiring skills in implementing these operations leads to obtaining consciousness of cognitive situations, the subject of acquaintance, goals and ways of achieving them and the criteria of quality of the obtained results. Conducting designing operations also facilitates performing an analysis, putting in order and utilising the results of learning, becomes the basis of conscious and consequent exploration of the world of physics

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[2]We check the capability of implementing cognitive operations in accordance with this model also while working with children of impaired hearing. We assume that suitably designed and prepared classes accompanied with multimedia presentations enable inculcating students with impaired hearing and speech to undertake conscious cognitive activities during lessons of physics.