Some remarks on the psychological approach in Didactics[1]

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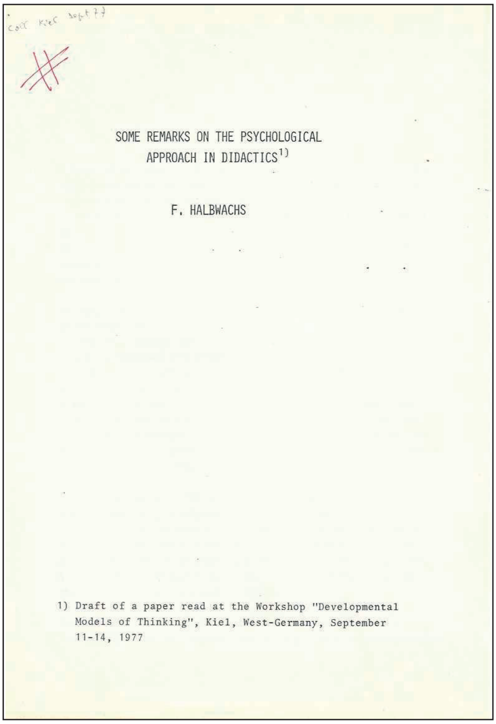

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SOME REMARKS ON THE PSYCHOLOGICAL
APPROACH IN DIDACTICS[1)]

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1) Draft of a paper read at the Workshop "Developmental Models of Thinking", Kiel, West-Germany, September 11-14, 1977

I feel rather puzzled to discuss the relevance of developmental models of thinking in science instruction. First, because I heard during the first workshop about developmental models, I learned about many topics I did not know until now, and so I shall need a long time and many experimental research projects to appreciate the usefulness of these recent models for science instruction. On the other hand, the notion of a psychological model for the functioning and development of a cognitive system is difficult to define clearly. As a physicist, I consider the models of the real world as complete systems of concepts quite rigorously defined through their mutual relations, such that logical and mathematical operations performed on these concepts can yield new knowledge about the processes that occur in the real world. Therefore, the Newton gravitation model allows the physicist to calculate with a pencil and paper, and to rigorously forecast the motions the planets perform in the sky.

In fact, it is just the mastering of such models, which constitutes, at the deepest

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[1] Draft of a paper presented at the Workshop "Developmental Models of Thinking", Kiel, 11-14 September 1977 (typed text, retrieved from Halbwachs archives, 2024).

level, the basic purpose of the training of the scientific conception of the world, the central aim of science instruction. Thus, we can say that our present discussion deals with the study of psychological models of model building and model using activity, that is, models at a second degree.

However, these functional and developmental models of intelligence are still quite far from the status, completeness, and efficiency of the scientific models that physicists are using to handle; these psychological models are far from providing, as the physical ones do, adequate mastery of the field of phenomena they are considered to represent. Therefore, in my opinion, if full knowledge of the theories of intelligence is necessary for the progress of Didactics, these theories can give in their present stage only punctual and qualitative statements for science instruction.

Nevertheless, these latter statements are very pertinent in contrast with the ideas and principles enrooted in the people and institutions of teaching, where the specific features of the structure of the pupil's and student's intelligence are generally ignored, as this intelligence is very often looked at as an empty field, the part of the teachers being to endeavor to fill this field with successive and well-ordered strata of knowledge taken from the cognitive system of the teacher himself.

In the following, I shall only quote some instances of light that can be thrown on the pertinent ways of science instruction by a theory of intelligence - here, the theory of Piaget - and of the disagreement of these conclusions with respect to the principles of classical science instruction systems.

A beautiful example of the lessons that didactics can draw from psychology is the actual building of so-called operative invariants, acting as key concepts of scientific representations. It is well known that Piaget assigns in his operative systems to the attainment of the conservation of matter (quantity of substance, weight, and volume).

Let us recall that, in the classical experiment of the clay ball, three types of arguments are used by children to affirm the efficiency of the scientific models the physicists use, which are far from providing, as the physical ones do, the adequate mastery of the field of phenomena they are considered to represent. Therefore, in my opinion, if full knowledge of the theories of intelligence is necessary for the progress of didactics, these theories can give in their present stage only punctual and qualitative statements for science instruction. Nevertheless, these latter statements are very pertinent in contrast with the ideas and principles enrooted in the people and institutions of teaching, where the specific features of the structure of the pupil's and student's intelligence are generally ignored, as this intelligence is very often looked at as an empty field, the part of the teachers being to endeavor to fill this field with successive and well-ordered strata of knowledge taken from the cognitive system of the teacher himself.

In the following, I shall only quote some instances of light that can be thrown on the pertinent ways of science instruction by a theory of intelligence - here the theory of Piaget - and of the disagreement of these conclusions with respect to the principles of classical science instruction systems. A beautiful example of the lessons that Didactics can draw from Psychology is the actual building of so-called operative invariants, acting as key concepts of scientific representations. It is well known that Piaget assigns in his operative systems to the attainment of the conservation of matter (quantity of substance, weight, and volume). Let us recall that, in the classic experiment of the clay ball, three types of arguments are used by children to affirm their conservation of substance: the argument of reversibility, the argument of compensation between breadth and length (the one based on perceptual cues, which are in fact relative to volume, and implicitly have the status of an experimental validation), and the plain obviousness: nothing was removed or added, so it is the same.

In an experimental study on air and gases performed in school conditions with 11-12 years old children, we encountered the same problem, except that for gases, volume, and quantity of substances change independently. After reproducing Piaget's experiments by decantation of air below the water, and quite satisfying answers, we filled a syringe closed at its extremity with air, and then varied the volume by pushing or pulling the plunger. The children answered unanimously: the air takes up less room, or more, but we always have the same quantity, because nothing was removed or added.

The answer to this question is interesting. This shows that, as was started by Piaget, for clay and liquid, as well as for air, it is the conservation of the substance that is directly asserted, not that of the volume. This shows that this kind of conservation has nothing to do with any perceptual or experimental validation but follows from mere logical obviousness. Therefore, the child owns a central concept, the *quantity of air*, which is defined and constituted directly through its conservation, that is, through its logical properties. More precisely, this quantity is thought as supporting an operation or being its object. This logical concept is completely built up among 11-12 years old children, and it does not need to be formally defined or proved through experiments; it can be introduced just as it is in didactical statements, the child understands directly what is concerned.

Therefore, we justify a didactical approach that transgresses the imperative rules of the classical teaching doctrine, which would require that the quantity of a gaseous substance would be defined as a numerical amount, namely the mass, measurable through weight, and that its conservation would be experimentally established through the weighting of the gas and after compression. This proof would be very difficult to follow up in practice under school conditions. In addition, it calls for other concepts that are much more difficult to grasp, such as Archimedes' pressure in the atmosphere.

The constituent part played by the operations (in Piaget's meaning) in the buildup of the concepts considered as invariants is quite general. We found this again in the case of the notion of a quantity of heat through pedagogical experiments performed over

12-13 years old pupils. These children spontaneously assert that a piece of iron, heated over a gas ring, gradually receives some heat that enters the iron. After removing the heat source, the heat moves away to the air in the room. By immersing hot iron in a glass of cold water, the heat passes from the iron to the water, so that the iron cools down, while the water is warmed up to a specific degree. Its temperature grows up higher if we have a larger piece of iron, because it contains a larger quantity of heat. They also assert that it is the same quantity of heat that has left the iron, and which has entered the water, so that nothing was lost or created.

These statements are conceptually trivial, but an important feature is that the conservation of heat is asserted before any experiment takes place. It once more results from the building-up of an operational invariant, which is defined through its auto-conservation. It seems interesting to point out that in the history of Physics, the conservation of heat was likewise asserted before any definition of the measurement of the quantity of heat, that is, before any experimental evidence. And this was built up through a theory which looked at the heat as a special fluid, namely the "caloric," which constituted a material picture of the property of transmission with conservation. Here, too, this remark yields to a quite pertinent approach for an elementary teaching curriculum on the science of heat, which consists of simply dealing with the heat as being a quantity that travels, flows from one body to another, and is always conserved.

Other examples are related to the preceding ones. Particularly, according to a colleague of mine, Prof. Lemeignan, who experiments in Paris on the conceptions of the transformation of energy amongst 14-15 years old children, it seems established that there exists an intuition of a quantity transformable from one form to another one without increasing or diminishing, provided that account is taken of all that is "wasted" in the forms of heat, friction or Joule effect, so that we have once more a basic concept which is constituted as an operational invariant, irrespective of the measuring processes of the energy under its different forms, and of the experimental validation of its conservation property. In addition, it is interesting to note, from a historical point of view, that the first actual statement of the principle of conservation was published by Robert Mayer under a logical and aprioristic form a little time before the publication of the well-known Joule experiments.

The quoted experiment - like mine - is performed on didactical and school-oriented grounds, with the aim of building proposals for a new curriculum in Physics instruction for the last year of obligatory school in France. Therefore, a simple but precise comprehension of the technology-oriented concept of energy, its qualitative forms, and quantitative transformation balance is very important from a social point of view. This task is made much less difficult by starting from a basic concept stemming from the spontaneous cognitive representations of the child and ignoring the conventional principles of the classical experimental method for correctly building this concept and its conservation law in the context of adult logic. Of course, we must reconsider the scientific foundations of the naive but correct intuition of the child.

Because of lack of time, I shall not go into further examples of other structural features and their application to instruction problems. In conclusion, I prefer to propose a few statements concerning the divergence of ordinary teaching principles in Physics and those derived from Cognitive Psychology considerations.

The classical scheme - observation, hypothesis, experimentation, underlying the methodology and epistemology of Physics - leads, as teaching is concerned, to the following features, which are found in various forms in curricula and schoolbooks:

1. The prominence of abstraction: physical relations deal with entities - namely, the terms of the hypothesis that are constituted as idealized observable phenomena (e.g., the material point, the light ray) or through an abstraction of characteristics that are common to different physical objects (e.g., force).
2. The prominence of quantitative concepts: the physical relations are generally represented by "formulas" or "equations" which relate numerical qualities.
3. The prominence of measure: physical quantities may only be coped with and introduced in formulas after it was completely stated how to obtain their value, that is, when their measurement procedure was precisely described.

These principles preclude the teaching of any physics topic before the pupils have learned how to manage the corresponding mathematical tools. Therefore, until the present year, when reform occurred, the children in France had no teaching in physics at all, up to the end of obligatory scholarity (16 years old). We are led by our experiments and many others, and based on Cognitive Psychology, we propose certain principles that are especially valid for young pupils, which are largely contrary to the preceding ones.

1. Before he is capable of a certain level of abstraction - or before he can be led to this level through an appropriate pedagogy - the child knows how to correctly treat some concrete situations, and even how to grasp the general relations underlying these concrete cases. By deepening and explicating these forms of relations, he can formulate relations in their general forms without breaking contact with the known concrete world. From this, by relating different but analogous concrete situations, he can lift his reasoning to the abstraction level.
2. Before being motivated - and before being capable - to "define" through a precise sentence the basic notions of Physics (let us say velocity, or light), the child often builds up a direct and global "idea" what may be called an "insight." In this form, he can perceive and clearly announce the relationships that rule these intuitive notions. For instance, 14-year-old children easily accept and often anticipate that a (concrete) force acting on a massive body increases its velocity before being able

to clearly define either force or velocity. As he further will learn how to render precise - and finally to define - these notions, the relations he has spontaneously perceived between them will provide him with reference points which will help him to "understand" these rigorous definitions from his underlying concrete insights.

3. In the cognitive genesis of physical relations, the qualitative aspect appears before the quantitative aspect. It is grasped sooner and with more striking obviousness. Therefore, in this respect, the most pregnant relationship is causality: this cause produces this effect, this agent produces this phenomenon. This relationship provides the child with an essential key to accounting for and understanding what happens. This must be the starting point for pedagogical proceeding, which, of course, goes beyond later and is discarded because of its metaphysical character.
4. The use of quantitative tools begins with the mere conception of the direction of a variation, that is, with the comparison of two-order relations (this is the "constituting function" of Piaget): this factor produces a variation of the other one in the same or opposite direction, or it produces no variation. A preliminary intuition of this kind yields an essential basis for the child to clear explicit mathematical functions (Piaget's "constituted functions"). It is to be clearly formulated at first to avoid, in many cases, not that the child gives false statements but that he gives absurd statements.

These are a few consequences that can be drawn from psychological knowledge concerning science instruction.