THE CONCEPT OF FORCE AS A CONSTITUTIVE ELEMENT OF UNDERSTANDING THE WORLD

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ABSTRACT

This paper concerns interpretation and constitutive elements of understanding the world, both of which are treated in relation to the concept of force. Studies are criticized in which students' conceptions are formulated, without further clarification, in terms of the word 'force'. From such reports it can neither be concluded what students believe nor how their beliefs relate to science. Instead, reasons or criteria for applying 'force' need to be made explicit. Those reasons concern the effects that forces produce, namely deviations from an influence-free state; they also concern their sources, as made explicit in laws from which, for a given situation, the forces acting in it can be derived. The general concept of force, thus associated with the two-tier explanatory strategy of specifying (1) influence-free states and (2) force laws to account for deviations from those states, is a constitutive element of understanding the world. Within the constraints set by this explanatory strategy, the concept of force can still be variously applied, both in everyday and in scientific explanations. The differences between these various applications are partly anchored in distinct explanatory interests.

1. INTRODUCTION

There is quite some consensus about one cause of the ubiquitous finding that students do not learn as much as was hoped for. A student entering a science class is not a *tabula rasa* but already has conceptions: domain specific beliefs; more general ones concerning the nature of science, epistemology, or ontology; and attitudes other than beliefs, such as motives, interests, and affects. Opinions begin to diverge concerning the status of students' prior conceptions and how to properly take them into account. Some claim that the prior conceptions 'are often in stark contrast to the science conceptions to be learned' and that 'major restructuring of the already existing knowledge is necessary' (Duit, 1999). Others argue that this view 'overemphasizes the discontinuity between students and expert scientists' and think of students' prior conceptions as 'resources for cognitive growth' (Smith *et al.*, 1993).

One major focus of this paper is a question that ought to precede the further question if – or in what sense – students' conceptions are impedient or expedient to their learning of science. This question is: what is the content of their conceptions? I raise this simple question, because I have doubts about the validity of a lot of

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research on students' ideas. The answer to this question, with respect to the concept of force, introduces the other major focus of this paper: a discussion of the relations between common sense and science in terms of constitutive elements of understanding the world.

2. THE PROBLEM OF INTERPRETATION

In early studies on children's pre-instructional theories of motion (Halloun & Hestenes, 1985; Gunstone & Watts, 1985), it is reported that children seem to operate with basic intuitive rules such as:

- Sustained motion needs a continuous force.
- If an object is in motion, it has a force in the direction of its motion.
- If there is no continuous supply of force, the force of an object wears out.
- Forces can be imparted by agents and transferred from one object to another.

Of course, children or lay people do not always frame their ideas in these exact words. But it is a small step from 'If he wanted to keep moving along he would have to keep pushing' (an example of what a child actually said, cf. Gunstone & Watts) to 'Sustained motion needs a continuous force'. So, it is plausible to assume that the child would have assented to the latter sentence. If children and lay people can be said to hold the intuitive theory in this sense, what follows?

According to many researchers the intuitive theory is 'at variance with the principles of Newtonian mechanics' (McCloskey, 1983). I agree that 'Sustained motion needs a continuous force' seems to be contradictory to Newton's first law, and that 'to have a force' is meaningless in Newtonian mechanics. But does it follow that the intuitive theory contradicts Newtonian mechanics? I think not. Consider:

S. Sustained motion needs a continuous force.

Children and lay people would assent to S, while Newton would dissent from it. This only implies they have contradictory beliefs, however, if all parties understand S in the same way, i.e. if there is identity of meaning. But *does* students' pre-instructional concept of force, in particular, match the Newtonian one? Most researchers probably hold that it does not. My criticism begins when it is left unsettled what, then, students' pre-instructional concept of force is, for this also leaves unsettled what children and lay people believe when they assent to S. Only *after* all this is settled, can one ask whether their belief contradicts any of Newton's beliefs. The same criticism may apply to researchers who hold that at least some of students' conceptions are in agreement with science. In the case of a spring that one holds compressed, both a student and a physicist assent to 'The spring exerts a force on the hand'; and in the case of a book lying on a table, only the physicist assents to 'The table exerts a force on the book'. On this basis nothing can be concluded, as yet, about beliefs. Neither does it follow that in the latter case student and physicist have contrary beliefs, nor that in the former their beliefs are in agreement (cf.