Introduction

Metaphors around fluids abound when teaching is discussed. One of the most frequent images in didactics is that of filling an empty vessel with knowledge, an example of what the learning being is *not*. Nor is the teaching community a passive receptacle for the constant stream of research-based findings meant to make teaching methods more effective. What kind of information can be of practical use to teachers who may have been disappointed before by what they call fine theories, and who have to make decisions on problematic situations every day, to analyse them and deal with them? There is a consensus that looking into what the "vessels" contain *before* being taught, i.e. the common ideas of pupils, is useful; this can be done, and this work is already well under way. Going on to express views on teaching, however, is more risky.

To return to the analogy with fluids, the teaching situation can be compared to water running down an uneven terrain – perhaps getting caught in great valleys where it was not meant to go. There are springs of water, too, there is energy, reactions are set off – these may be small, but they could have unforeseen effects. Helping students to build their knowledge can be likened to opening up channels in that pitted, irregular terrain, so that thought can travel faster. Building the road to knowledge involves mastering any number of complex parameters: how should we go about it? Research has not yet come up with an answer to this question.

The aim of this book is limited. It may seem to add very little to the enormous range of considerations on teaching, as it stresses points on which there is by now a wide consensus, such as the importance of students' preconceptions, and that organised intellectual activity is an essential condition for the appropriation of knowledge. In this book, all our considerations begin with "critical details"[1], apparently minor aspects of teaching which can, in fact, bring about noticeable changes, and have an impact on learning. Thus, to take up our metaphor, grains of sand may deflect little streams. Contrary to what one might think, describing these little adventures is not trivial, especially if it helps predict the outcome of a variety of situations.

Why is it that famous researchers in didactics, whose views on teaching are globally similar, often suggest strategies that are radically different when it comes to details, even though they have the same kind of public and institutional constraints in mind[2]? In fact, any carefully constructed teaching strategy rests on at least three analyses: the content one aims to teach, the ideas and forms of reasoning available to the learner *a priori*, and the conditions that foster reputedly effective learning mechanisms. Researchers may well have identical views on the third point, but different approaches as regards the first two. They are generally agreed on their assessment of learners' preconceptions, which have been studied for some thirty years[3]. Teachers who are interested in pedagogical advances also have a fairly good knowledge of the *a priori* modes of thought of their public[4]. Views diverge, however, on what use should be made of what is "already there". Teaching objectives, i.e. the parts of the taught subject one chooses to highlight, are particularly determining. Yet in this respect, there is rarely any agreement on content analysis. This may seem surprising, since the content of a subject such as physics seems fixed and unchangeable. But choosing what light to cast on the various elements that make up the content, in view of the difficulties that students are likely to experience, leaves much more room to manoeuvre in than we would think, even at a single grade level. One of the aims of

[1] Viennot 2001a,b.

[2] The topic of "materialised rays of light" is developped in chapter 1. In view of the findings of French researchers (Kaminski 1991, Hirn & Viennot 2000), its use as an introductory device is questioned there, although its use is presented as a model "constructivist" strategy by Driver *et al.* 1994, without any reservations.

[3] For a review of the research, see Driver *et al.* 1985, Johsua & Dupin 1993, Viennot 1996, Tiberghien, Jossem & Barojas (Eds.) 1998; for an extensive bibliography, see Pfundt & Duit, 2001.

[4] At least, such was Hirn's conclusion on the middle-school optics teachers who volunteered for a study (Hirn 1998; see also Hirn & Viennot 2000). Similar findings were obtained by Italian researchers in the field of elementary mechanics. These two studies were conducted for a European project (CE: DGXII, Targeted Socio Economic Research programme, Science Teacher Training inn an Information Society project, co-ordinated by R. Pinto, Universitat Autonoma de Barcelona, 1997-2000), which we discuss further on.

this book is to illustrate this idea, and to show the impact it can have on teaching practice. Some major elements of practice are discussed in the first chapter: these analyses, all based on the description of details, are intended as guidelines, to orientate the teacher's attention when he/she determines what to do in class. To spare the reader, the specific examples illustrating each of these sections have been chosen from the same field, i.e. geometrical optics. After demonstrating how content can be selectively highlighted, we study the following points: the adequate level of explanation (how much should we explain?), the impact of graphic documents, linking practical experimentation and comprehension, the articulation of concepts.

Then, we make some suggestions for teaching five specific topics; all of them were designed with the same concerns in mind as those presented in the first chapter. Obviously, it would be impossible to cover everything that is ordinarily taught in physics, even at the secondary school level. We broach only a few topics, to illustrate representative types of content. The first two – friction between solids and pressure in fluids – concern *contact interactions*; in the first case they are relatively local, in the second, they are distributed over a greater volume. In each case, we consider the merits of using *modelling on an intermediate scale*, between the microscopic and the macroscopic levels. Then we deal with the superposition of electric fields for conductors at equilibrium, to analyse the superposition of physical effects. The next topic associates the superposition of coherent waves and optical imagery, providing an example of how *theories often associated to different situations can be used simultaneously* – here, in geometrical optics and wave optics. Finally, several fields of knowledge overlap in the study of colour phenomena: the psychology and physiology of perception, physics and technical aspects. The proposed sequences are aimed at students in the last years of secondary schooling or the first university years, although elements of the first two topics, and of the last one, can be profitably introduced in the very first years of junior high school. There is nothing particularly modern about the topics considered here; they are quite conventional. Of course, we do not rule out the possibility of introducing topics from modern physics at various levels. But the results of much consideration and research are available on these long-taught topics, and they constitute a relatively reliable framework in which to illustrate our approach.

Each of the sequences described is discussed in the light of the guidelines identified in the first chapter. We then provide some data on which the evaluations are based. Indeed, although there are a great many suggestions on what to do in teaching, no matter how successful their authors may claim them to be, without a monitored assessment of some sort, what comes out most clearly is one individual's enthusiasm. Many benefits can stem from personal and thought out beliefs. But we have chosen to concentrate on sequences whose results have actually been evaluated among pupils or students, although some of these studies are more complete than others.

The data on which our evaluation is based shows that the cumulative effect of various well-placed grains of sand can, in fact, orientate the flow of a river of knowledge. This is all the more important if one considers past failures. Inspired ideas, though based on research, do not always lead to success – not by a long shot. As is shown in one of the sequences described here, in one instance they had a negative effect, due to their being incompletely thought-out.

Finally, one major point must be stressed; we still do not know nearly enough about how to optimise the joint development of research and teaching. Teachers have the final word on teaching practice. It is teachers who, acting within a thousand constraints, determine what the teaching situation will be. If one accepts that details are decisive – crucial, even – this gives their every decision even greater importance, and it is very useful to know how they react to a given suggestion. We provide information of this kind. The point is that this book will not have the slightest impact unless the facts and the analyses it contains are at some point recognized as valid by a teacher in a classroom situation.

Such is our goal. Moreover, we hope to convince the reader that, even in topics other than those dealt with here, so-called "details" of teaching practice are crucial. If neglected, they are likely to lead to quiet fiascos. When they are well-negotiated, however, they can trigger off remarkably positive reactions.

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