Chapter 1

Introduction

1. The topic of mechanics

An important aim in teaching and learning of mechanics, I think, is that students come to understand and appreciate mechanics for the right reasons. Newtonian mechanics has been one of the great successes of physics or science in general. It can be seen as a prototypical example of capturing natural phenomena in quantitative expressions that have such a wide applicability that they can be called universal laws. The power and simplicity of Newtonian mechanics makes the heart of many a physicist beat faster. Could students be made to appreciate mechanics for the same reasons? If so they would have truly understood something about mechanics! I think it might be worthwhile to find out to what extent this is possible.

Learning mechanics is notoriously difficult and much research has been devoted in mapping and understanding these difficulties (e.g. (Hake, 1986)). Concerning possible causes of this lack in understanding, the mainstream opinion appears to be that the 'naïve' conceptions of students are very different from the 'expert' Newtonian conceptions and that therefore a transition between those is difficult to achieve. Far less research was directed at remedying these problems, which makes some sense, since one first has to diagnose the disease before trying to apply a cure. Another reason for this lack of remedies is that science education as a field of research is very young. Roughly speaking the history of the sciences shows a development in particular sciences (like for instance biology) from a descriptive level (*what* kind of things are we dealing with) to a explanatory level (*why* are the things doing the things they do) to an applicatory level (*how* can we use the understood behaviour of things). The science of 'science education' is in many respects still in the early stage of description. However, at the same time many people involved in science education are more interested in the applications. This results in rather explorative research, since thoroughly tested didactical theories have not yet been developed. This research too will show the resulting tentative exploring that comes from searching for applications without the aid of a mature didactical theory.

The earlier mentioned metaphor of a disease (with the symptoms of learning difficulties in mechanics) also illustrates another point, namely that the cure one applies depends on the kind of disease that is diagnosed. It will turn out that part of the reason for the first steps towards a cure that I have taken lies in the fact that I tend to diagnose a different disease than many other researchers.

2. Overcoming difficulties in learning mechanics

My diagnosis of the difficulties in learning mechanics and the related approach for remedying these use the basic idea that although there obviously are differences between the Newtonian way of explaining motions and the common sense way, they also have something in common, which may be used productively for teaching/learning mechanics. What they have in common, I think, is what may be called an explanatory scheme. This explanatory scheme consists of the assumptions that a particular kind of motion needs no explanation and that motions that deviate from motion of that kind must be accounted for in terms of influences. I call the assumed motion that needs no explanation an 'influence free motion'. Newton's assumption of an influence free motion is motion with uniform velocity. Deviation from such motion is caused by influences, which Newton called forces. Common sense explanations of motion use the same explanatory scheme. Take for example the explanation that for keeping speed on one's bicycle one needs to keep pedalling, because otherwise one would come to a stop. In this one can recognise the combined use of an influence free motion (gradually coming to a stop) and an influence (pedalling) that causes a deviation from this kind of motion. The 'expert' explanation may aim at theoretical values like broad applicability, simplicity and empirical adequacy, while the aims of a common sense explanation are related to practical usefulness and may depend on the context. That is, I interpret the differences between expert and common sense not so much as differences of belief, but rather as differences of aims and motives.

A common sense explanation of a motion, like that you have to keep pedalling in order to keep speed on a bicycle, is usually straightforward. In comparison, the description of such an explanation in terms of the explanatory scheme for motion, which involves an assumption for an influence free motion in conjunction with an identification of suitable influences that account for deviations from this influence free motion, may appear very difficult or even awkward. Indeed, the scheme's use is not in the first place of a practical nature, but rather lies in the fact that it allows one to talk *about* explanation of motion. From this theoretical perspective, moreover, its broad applicability can be appreciated, not only in the sense that one can see it as underlying various explanations of motion, but also in the sense that one can begin to wonder whether, perhaps, *any* motion could be explained in this way.

As I just suggested, the differences between naïve and expert conceptions may be much smaller than they appear, in the sense that there are structural similarities between them and that the differences between the expert and the novice are to be found in their respective motives and aims. Of course this does not mean that students already know Newtonian mechanics and even less that they are willing to learn it. In fact, they will have to expand their knowledge considerably, and how they can be made to want this is a big educational problem.

Apart from the explanatory scheme's possible immediate use in a course in mechanics I would like to suggest that the explanatory scheme also provides a 'vocabulary' for clarifying or addressing what students actually say when they later explain motion and for pointing out the differences and similarities between their explanations and the Newtonian ones. In this sense I think that having available this explanation vocabulary can also be of help in discussing, with students, the usual problems in understanding mechanics.

Although this idea might be applied to a complete mechanics course for secondary education, such an endeavour would be too time consuming and unnecessary for exploring how this idea may be made productive. I therefore decided to apply the idea in a design of an *introductory* course of about 10 lessons for upper level pre university students (age 16). In an introduction of any study topic one expects to find what the topic is about and some indication of the importance of studying the topic. In my case this fits in nicely with my first two aims of giving students some sense of how mechanics works and the power and range of mechanics.

3. Research question and method

My research question is how the idea of a common explanatory scheme in common sense and Newtonian mechanics can be made productive in teaching/learning mechanics. How this can be made productive, concrete, in real life education, is still an open question I am going to explore in this thesis. This question concerns both how the explanatory scheme can be used in a design of an introductory course that will lead to my educational aim (of making students appreciate the power and range of mechanics and know how mechanics works) and whether this course will provide the vocabulary to address the usual learning difficulties to be used in the regular course following this introductory course.

Since my research question is a design question, the method followed is a design experiment (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) sometimes also called developmental research (Lijnse, 1995).

A starting-point in my design is the idea that it would be worthwhile if students in each successive learning activity can see the point of doing that activity, how it builds on or makes use of the preceding activity and attributes to and prepares for the next one. All ‘local’ activities are leading to a ‘global’ goal students have some perspective on (however vague) and have some reason for achieving. This is sometimes called a problem posing approach (Klaassen, 1995).

This idea together with the idea of the explanatory scheme will be worked into a design, which will be described in a scenario. A scenario is an important instrument in this kind of research. It describes and justifies in considerable detail the learning tasks and their interrelations as well as the actions that students and teacher are expected to perform. It can be seen as a hypothesis, as a prediction and justification of the teaching/learning process that is expected to take place. As such, it also enables the researcher to precisely observe where the actual teaching/learning trajectory deviates from what he expected, and thus to test his hypotheses in a valid and controllable way.

In my scenario a justification will be given for each teaching/learning activity, why this particular activity should take place, what the goals of the activity are and why this activity would be expected to meet these goals. All successive activity goals should of course lead to the course goal of giving students some sense of how mechanics works and some appreciation of its power and range.

Expectations for each teaching/learning activity will be compared to the actual teaching/learning process that takes place. The precise expectation determines what sort of data, e.g. observations, video- and audio recordings, interviews with students and teacher, students’ written materials and questionnaires, will be collected. These can then be analysed by qualitative interpretative methods. This will give information to what extent the teaching/learning activity goals are met and this in turn sheds some light on the more general course goals.

4. Content of this thesis

In chapter 2 the context of this research will be described. Some goals for mechanics education, problem analyses of what might be difficult in reaching those goals, approaches of remedying these difficulties, research methods for investigating these approaches and the results they yielded will be presented and critically discussed. After that, chapter 3 continues with a broad description of my own attempt, in the light of the discussed alternative approaches. Here the idea of the explanatory scheme will be extensively presented as a possible means of reaching the desired educational goals. The research question will be further elaborated upon and the method of design experiments will be presented as a useful way of answering the research question. Chapter 4 describes how the test of a first design resulted in ideas for revising it and broadly describes the resulting second design. Also the way in which the teacher was prepared for executing these designs will be addressed there. Chapter 5 zooms in on the (in chapter 4 broadly described) second design. It contains a detailed description of the second design, which includes the revisions that were based on the testing of the first design. Chapter 6 describes the results that were obtained from testing that second design. Finally, in chapter 7 these results are reflected upon, which will result in an answer to the research question and which will point to directions for further research.