A PERSPECTIVE ON THE DIFFERENCES BETWEEN EXPERT AND NOVICE PERFORMANCE IN SOLVING PHYSICS PROBLEMS

Audrey B. Champagne, Richard F. Gunstone, and Leopold E. Klopfer

INTRODUCTION

There has been in recent years a dramatic growth of investigations of student world views of force and motion. These investigations, often motivated by a concern with student understanding of mechanics, have reflected a world-wide interest in these issues (e.g., Champagne, Klopfer and Anderson, 1980; Driver, 1980; Gunstone & White, 1980; Hewson, 1981; Osborne & Gilbert, 1979). The existence of world views logically antagonistic to the tenets of mechanics is now beyond dispute, as is the resilience of these views in the face of standard forms of physics instruction. It seems clear that the significant issues in this area are now the specific instructional implications of these findings.

THE INSTRUCTIONAL PROBLEM

Classical mechanics is widely perceived to be difficult to learn. Researchers considering this phenomenon have often investigated particular variables argued to be prerequisite to successful physics learning, such as mathematical skills, general level of cognitive development, and specific cognitive processes (e.g., Arons, 1976; Hudson & McIntire, 1977; Renner, Grant & Sutherland, 1978). The usual basic strategy adopted in such investigations is to show a correlation between a student characteristic (such as Piagetian level of cognitive development) and success in physics. Often instruction is then modified to take account of student inadequacies with respect to this concept, and the effect of this modification on learning is probed. However this strategy has produced only limited results (e.g., Mallinson, 1977; Peterson, 1979).

The studies of student world views of force and motion mentioned above provide another perspective on the difficulties involved in learning physics. These studies give empirical support to arguments that students come to introductory physics courses with firmly embedded conceptualisations of how and why objects move. The conceptualisations have features which are broadly Aristotelian. Many writers have commented on the historically great effort involved in replacing the Aristotelian view of motion in physics. Dijksterhuis (1961) goes further:

To this day every student of elementary physics has to struggle with the same errors and misconceptions which then had to be overcome, and on a reduced scale, in the teaching of this branch of knowledge in schools, history repeats itself every year. The reason is obvious: Aristotle merely formulated the most commonplace experiences in the matter of motion as universal scientific propositions, whereas classical mechanics, with its principle of inertia and its proportionality of force and acceleration, makes assertions
which not only are never confirmed by everyday experience, but whose direct experimental verification is fundamentally impossible ... (p.30).

The research described in this paper leads to an instructional design approach which is an alternative to consideration of issues such as mathematical skills or level of cognitive development. The approach uses an analysis of traditional instructional tasks for the purpose of specifying the underlying cognitive processes and structures necessary for the successful completion of the tasks. That is, a cognitive analysis of instructional tasks, rather than a logical analysis, is used to arrive at appropriate instructional goals. In particular, we consider two broad aspects of differences between physics experts and novice physics students which are relevant to physics problem solving. These aspects come from recent cognitive psychology research into processes and structures used by experts and novices in physics problem solving, and from science education research into student world views. From these we advance simple models of expert and novice physics problem solving and then use these models to consider appropriate goals for physics instruction.

EXPERT AND NOVICE PROBLEM SOLVING

The focus here is on problem solving studies undertaken in the area of physics. We have discussed elsewhere both studies in other subject areas and the implications of the broader context of current views that learning is an active and constructive process, that existing knowledge/schema are of considerable importance to the process of coming to understanding through individual interpretation of material to be learned (Champagne, Klopfer and Gunstone, 1982).

Larkin (1979) analysed thinking-aloud protocols obtained from experts and novices while they solved physics problems. She found that experts perform an initial qualitative analysis of a problem before using appropriate equation(s) for the quantitative solution of the problem. Novices, by contrast, immediately search for an equation and do this by matching the information given in the problem with terms in the equation. This difference in problem solving process is shown in simple form in Figure 1.

EXPERT

Problem Statement —> Qualitative Analysis —> Equation

NOVICE

Problem Statement —> Equation

Figure 1: Expert and novice problem solving strategies.