INTRODUCTION

"A primary objective of the educational enterprise is to impart the cognitive skills involved in problem solving." (McMillan & Swadener, 1991, p. 661).

The context of the question.

Problem solving – commonly understood as the ability of individuals to apply their *prior* knowledge in *new*, somewhat unfamiliar, situations – has always been considered of the foremost importance by both teaching practitioners and educational researchers (Dewey, 1910, 1916; McMillan & Swadener, 1991; Tuma & Reif, 1980). Consequently, successful teaching of problem-solving skills has become a prominent goal of formal schooling.
A massive body of research exists in the general field of problem solving. Not surprisingly, a substantial part of that research focuses on physics, for two reasons. First, cognitive psychologists have found physics a useful field in which to explore the mental mechanisms of problem solving (Chi, Feltovich, & Glazer, 1981; DiSessa, 1981; McCloskey, 1982). Second, physics has – from its very inception as a separate academic discipline – placed a great emphasis on teaching problem-solving skills (Kiddle, 1883; Millikan & Gale, 1927; McDermott, 1975; Arons, 1981; Clement, 1993; Mazur, 1996, Kibble, 1999[1]). Pippard thus summarizes this emphasis: "… if he [the student] cannot make a good showing at the … problems, all his expertise in the realm of ideas is … vanity." (Pippard, 1962, p. viii). Nowadays, more and more students take physics: in 1997, high-school physics enrollment reached 800,000, or about 28% of the student population, compared with only 20% in 1987; also, annually, about 400,000 students take physics in college (Neuschatz & McFarling, 1999). Correspondingly, the need for successful problem-solving instruction in physics classrooms is more profound than ever.

The prevalent view in the physics education community is that such instruction must be based on thorough understanding of the mental processes involved in problem-solving. Meanwhile, numerous authors have noticed the immense difficulty of developing effective teaching strategies (Clement, 1993; Cyert, 1980; Mestre, *et al*, 1993; Pankratius, 1990). While quite a few researchers have claimed some degree of success, many of their claims are, in my view, seriously undermined by inconsistencies in research methodology and somewhat wishful interpretation of their results. All in all, it is fair to say that no reproducible teaching method has been shown to consistently improve students' problem-solving abilities based on the current state of understanding of the cognitive mechanisms involved in the solving process.
My research aims to advance this understanding in ways useful for practical applications. While I am under no illusion that my results will become a "silver bullet" in teaching problem-solving skills, I do believe that a positive difference will be made. The study advances the current understanding of problem-solving processes in physics and should be helpful in creating effective strategies in teaching problem-solving skills and in developing physics curricula.

Research questions and hypothesis.

My research questions are:

- Do bisociation and rigid knowledge play distinct roles in the process of solving physics problems?
- Is rigid knowledge or bisociation the most significant factor limiting the individuals' ability to solve non-trivial physics problems?
- What salient components can be identified within bisociation?

Based on my analysis of the current research (Korsunsky, 2000), my own experience of working with problem-solvers, and a pilot study (Korsunsky & Record, 2000), I hypothesize that:

- bisociation and rigid knowledge are distinct from each other;
- bisociation, not rigid knowledge, is the more significant limiting factor of the problem-solving abilities of individuals;
- at least some components of bisociation can be reliably identified in my study.

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[1] Note that the sources are listed chronologically rather than alphabetically – B. K.

Terminology.
Throughout this paper, I will use the terminology specific to physics education research on problem solving. For the convenience of the reader, I would like to provide the list of the key terms. The definitions of the terms – except for the ones proposed by me – are taken from the literature reviewed in Chapter 1.

Bisociation. I propose this term to denote the complex set of skills that help problem-solvers identify the *rigid knowledge* (see below) relevant to the problem situation[2].
Exercise. A task that requires good knowledge of previously taught procedures to be solved; in such tasks, the relevant knowledge is specified or otherwise made known (compare with *problem*).
Expert. An individual with a high proficiency in the domain.
Knowledge, declarative. Knowledge of facts and principles that apply within a domain.
Knowledge, procedural. Knowledge of actions and manipulations that are valid within a domain.
Knowledge, rigid. I propose this term as unifying the declarative and the procedural knowledge.
Knowledge, situational. Knowledge about the features of the typical situations in the domain.
Knowledge, strategic. Knowledge about planning the sequence of actions for the problem-solving process.
Misconception. A common erroneous physics-related belief held by an individual either prior to the instruction or afterward.
Novice. An individual with little proficiency in the domain.
Problem. A task that is challenging within the context of the individual's prior experience; it requires creative, "out-of-the-box" thinking to be solved; the knowledge necessary to solve the task is not specified (compare with *exercise*).
Schema. A large unit of knowledge that combines declarative, procedural and situational knowledge relevant to solving a particular type of problem.
Task. In this paper, a common term for *problem* and *exercise*.

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[2] This term was first proposed by Koestler (1964); however, as Perkins (1981; personal communication, 2001) explains, Koestler's meaning of the word is entirely different. Besides, the term, to my knowledge, has never been used in physics education research – so I "borrow" and redefine it with a clear conscience.