

NOTES ON THE NATURE OF REASONING SKILLS

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Whatever the nature of reasoning skills, such skills are rare [4], [2]. Thus, it would be desirable to develop support for them and to cultivate and strengthen them through proper education in reasoning. The background for my discussion is the development of support for reasoning skills that our research team has been conducting for some time (www.athenasoft.org).

Design of support or education for reasoning depends on concepts of reasoning skills. The essence of reasoning is to construct or evaluate relations of dependence. If D can be proved from A, B and C, there is a logical dependence between these items. A person has reasoning skills if s/he is capable of recognizing or constructing relations of dependence between possible items of knowledge.

A dominating view is that reasoning skills are exhausted by forms of inferences described by deductive or inductive logic. Such ideas of reasoning skills are influenced by formal logic. Aristotle's *Organon* formed the basis of teaching reasoning skills in university education up to the early 20th century. The success of propositional and quantificational logic under Frege and Russell provided a new model for reasoning. Text books in "baby logic" typically discuss translations into and out from these formalisms together with the logical properties, sometimes including the metalogical properties of reasoning. A parallel success for inductive methods has cast off statistics as a separate science of reasoning. Methods for testing, accepting and rejecting hypotheses are key elements of statistical inference, independent of domain.

The success of formalizations of deductive and inductive inference supports *the unitary view of reasoning skills (URS)*. This standpoint claims that reasoning relies on one or possibly two (deduction and induction) type(s) of skills that are independent of what we are reasoning about. It draws support from several (once) central philosophical theories:

1. Logicism, according to which all mathematical necessity is at bottom logical necessity. The only deductively necessary connections we need to accept are those of logic.
2. The regularity view of causation. All (seemingly) causally necessary connections whereby A produces B are really instances of a universally quantified schema "All instances of the A-type are followed by some instance of the B-type".
3. Explanation and prediction as inferences. To explain (or predict) the fact that C is to provide a set of universal laws $A_1 \dots A_k$ and initial conditions $B_1 \dots B_n$ such that we can deduce C (or sufficiently increase the probability of C) from these two sets.
4. Reasoning involves second order concepts, not domain dependent first order concepts.

Now, if URS were true, it would facilitate the design and development of software support and teaching of methodology. But there are disturbing facts about URS.

2 Bertil Rolf

First, it seems that professionals are notoriously bad at reasoning in spite of the fact that most of them (at least in the USA) have taken courses in "baby logic" or in statistics [4]. Second, it seems that traditional courses in critical thinking do not improve on students' capacity of reasoning. Third, there is a challenge from the research about "models, metaphors and reasoning" in the philosophy and psychology of science [1], [5]. Fourth, teachers of reasoning skills tend to voice complaints that students do not seem to benefit from the, often, mechanical transformation of arguments into standard logical form [3].

My tentative standpoint is that URS states a *necessary* but not a *sufficient* condition for good reasoning. There are general features common to good reasoning. But they do not exhaust reasoning skills. Reasoning skills are also related to the cognitive management of domain dependent models, showing dependencies of facts *beyond* the logical (deductive or inductive) relations between propositions describing those facts.

This standpoint is not uncommon. Its practical implications are that good reasoning relies on varieties of skills that can be supported or taught via different kinds of representations, some of them specific to the domain or phenomena under consideration.

It is not clear, however, in what way models contribute to our reasoning skills over and above propositions and inferences. In what way do we understand dependencies between facts better if we also use other representations than propositions and their interrelations? If we already know that the proposition stating C follows from those stating A and B, what "extra" cognition takes place when we understand the dependency of C on A and B via diagrams or graphs? Even if there is a subjective extra feeling of mental insight, are there also some extra cognitive tasks beyond logical inference performed with support of domain specific reasoning models?

A second problem is related to the qualities of good reasoning models. Some representations of dependencies seem to be better than others. What makes them so?

I will try to provide a partial answer to these questions, drawing on Tufte's work *Visual Explanations* and Pearle's book *Causality* [7], [6].

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