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Do students need to be taught how to reason?

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ABSTRACT

In this theoretical essay, the author addresses the existence of divergent evidence, portraying both competence and lack of competence in a fundamental realm of higher order thinking – causal and scientific reasoning – and explores the educational implications. Evidence indicates that these higher order reasoning skills are not ones that can be counted on to develop naturally among students exposed to a traditional curriculum. Instead, it is argued, such skills warrant attention in their own right as legitimate and significant educational objectives.

Recent efforts to assess the cognitive benefits of college experience, most notably the College Learning Assessment (Hersh, 2005), make it clear that higher order thinking skills are an expected outcome of education, at least by the college level. Less clear is how it is intended that students attain these skills. They are not taught explicitly during the college years, nor are they the object of instruction in the years leading up to college. Is it assumed that students exposed to a rich traditional curriculum will acquire these skills along the way? And, if so, is this assumption warranted?

Higher order thinking encompasses a very broad range of competencies. It is possible to address all of them only in very general terms. Therefore, in undertaking to bring empirical evidence to bear on the questions posed here, I identify and focus on several particular kinds of higher order thinking that come under the heading of causal and scientific reasoning. This kind of reasoning arises in identifying questions, accessing information that addresses them, examining and evaluating patterns in data, and making inferences (Klahr, 2000; Koslowski, 1996; Kuhn, 2002, 2005; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn & Dean, 2004; Kuhn & Pease, 2008). Although typically studied independently, causal inference and scientific inquiry entail many of the same reasoning skills (Kuhn & Dean, 2004). Moreover, causal explanation is the most common form of explanation people draw on in the course of everyday thinking (Lombrozo, 2006). There is little question that people are better off to the extent they can protect themselves from acting on the basis of faulty causal inferences and little question that we expect educated people to have learned to reason accurately about cause and effect, to avoid making unwarranted inferences, and to recognize them when made by others.

There now exists a substantial amount of scholarly research related to such reasoning. I make no attempt here to exhaustively review this literature, which has been done elsewhere, focusing on both scientific reasoning (Kuhn, 2002; Moshman, 1998, 2005; Zimmerman, 2000, 2007) and causal reasoning (Bullock, 1985; Gopnik & Schulz, 2004; Gopnik & Schulz, 2007; Lien & Cheng, 2000; Sloman, 2005; White, 1990), which as noted have tended to be studied separately. Overall, however, such research encompasses a number of distinct lines of work that portray strikingly different pictures of human competencies. Given the educational significance, it would be well to make sense of this divergence.

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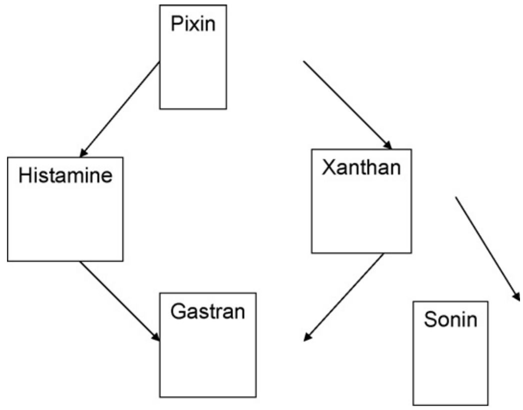

Fig. 1. Causal model, adapted from Waldmann and Hagmayer (2005).

1. Competent college students

Instead of undertaking any exhaustive literature review in this brief article, I identify and examine closely one or two studies, in each of several categories, as representatives of larger literatures of their type. I begin with the causal reasoning literature, an area of investigation which has seen substantial growth in recent years (Bullock, 1985; Gopnik & Schulz, 2004; Gopnik & Schulz, 2007; Lien & Cheng, 2000; Sloman, 2005; White, 1990). Much of this literature highlights the impressive competence college students exhibit in complex causal reasoning tasks. For the present illustrative purposes a study by Waldmann and Hagmayer (2005) is ideal, because it asks college students not only to make causal inferences but to make outcome predictions reflecting these judgments, the latter a lesser studied skill but one we also encounter in the studies considered later in this article.

Waldmann and Hagmayer propose a "top-down causal-model" theory, which they describe as a variant of Bayes net theories. The theory claims that people hold initial assumptions about hypothetical causal models and then fill in the parameters when presented with data (Waldmann, 1996).

I describe only one segment of one of the written tasks presented individually to students. On page 1, the student is presented the causal model shown in Fig. 1, depicting variables potentially involved in sleeping sickness. The model hypothesizes that mosquito bites cause production of the substance pixin. Pixin in turn causes xanthan, which increases the levels of both sonin and gastran. Pixin is also assumed to increase histamine, which generates gastran. No other causes or effects are known to operate. On page 2 appears a list of test results for 20 chimpanzees. For each chimp, binary information (elevated or normal) is provided for each of the five substances. Pixin is present half the time. On page 3, 20 new chimpanzees are introduced. The question posed is how many of the 20 will have an increased level of sonin, under two different circumstances. In the first case, all chimps have increased histamine levels; in the second case all have normal levels. According to the causal model, increased histamine is caused by presence of pixin, and pixin leads to increased sonin. Hence, answers should be 20 to the first question and 0 to the second. Mean responses (17.44 and 2.96 respectively) were very near to these normative values. In subsequent more complex variations involving intervention and probabilistic outcomes, performance was similarly near normative. The authors conclude their article by emphasizing their study's demonstration of "people's remarkable competency" to generate accurate causal judgments and predictions.

2. Competent preschoolers

The literature on causal inference skills among preschool children resembles the adult literature in its emphasis on impressive competence. A study particularly impressive in its demonstration of causal reasoning competence in young children is one by Schulz and Gopnik (2004). I choose it for illustration because it also is suggestive of competence in scientific thinking on the part of very young children. Preschool children observed a monkey hand puppet sniff varying sets of three plastic flowers, one red, one yellow, and one blue. An adult first placed the red and blue flowers in a vase and brought the monkey up to sniff them. The monkey sneezed. The monkey backed away, returned to sniff again, and again sneezed. The adult then removed the red flower and replaced it with the yellow one, leaving the yellow and blue flowers together in the vase. The monkey came up to smell the flowers twice and each time sneezed. The adult then removed the blue flower and replaced it with the yellow flower, leaving the red and yellow flowers together in the vase. The monkey came up to smell the flowers and this time did not sneeze. The child was then asked, "Can you give me the flower that makes Monkey sneeze?" Seventy-nine percent of four-year-olds correctly chose the blue flower, indicating their ability to identify causes in a multivariable context. In related studies, causal reasoning competencies are demonstrated among even younger children, 2 and 3 years old (Gopnik, Sobel, Schulz, & Glymour, 2001).