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The Problem-Behavior Map as Cognitive-Historical Analysis

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Introduction

Attempts to trace the path of scientific discovery have traditionally followed the lead of Simon (1969), who proposed that all reasoning could be elaborated by means of states, operators and problem spaces. Our examination of physicist Michael Faraday's 1831 experimental notebooks has shown that a Simonian analysis is not ideal for some historical studies of scientific discovery. We have developed the Problem-Behavior Map (PBM) in order to study paths of experimentation and reasoning in historical data.

Faraday and the path of science

Much of Faraday's science lends itself towards cognitive-historical investigation, especially the formation of his electromagnetic field theory (Nersessian, 1985). In particular, his detailed experimental notebooks have been utilized as a testbed by several researchers in the cognitive science of science (i.e., Tweney, 1996; Gooding, 1992).

We have attempted to formulate an understanding of Faraday's October 28 and November 4, 1831 researches in magnetism, electricity and motion. This period was just subsequent to Faraday's discovery of electromagnetic induction and instrumental to his completed field theory, for which his "sphere" diagram was essential.

To understand how scientific discovery proceeded for Faraday, one must acknowledge his researches as being a series of investigations over time. Attempts to describe the path of a scientist's reasoning have been put forth by numerous researchers (including Tweney and Hoffner, 1987; Gorman, 1994; Kurz & Tweney (in press)).

Tweney and Hoffner (1987) adapted problem-behavior graphs to trace a portion of Faraday's researches. Similar attempts for the current project failed, as Faraday moved quickly from one problem space to another, necessitating an analysis that incorporated multiple problem spaces. Gorman's (1994) graphical map addressed the evolution of the design of Alexander Graham Bell's telephone, but included data far-removed from the level of notebook entries (i.e., patent sketches). As neither of these methods were completely satisfactory for understanding the experiments at hand, we developed the Problem-Behavior Map.

Problem-Behavior Maps

The PBM operates on three levels: (1) a level within experimental episodes structured similar to a problem-behavior graph; (2) a maplike structure at a meta-episodic level; and (3) placement of the PBM in a historical context.

Within each episode of the problem-behavior map, we characterized the experimentation in terms of goals and states in problem spaces. For example, a graph of Faraday's experiments §102 through §114 showed that Faraday systematically varied apparatus arrangements within his working problem space (manipulating position of magnet, rotation direction of plate, and position of galvanometer leads). Yet, he changed problem spaces and variables within the day's researches, requiring us to divide the experimental record into episodes.

Thus, the PBM necessitates an account of potential "moves" from one episode to another. To make the transitions between problem spaces understandable, a maplike structure (Gooding, 1992; Gorman, 1994) is proposed. The resultant account of these transitions is necessarily informed by the historical context (i.e., the role of these experiments in Faraday's complete field theory).

By using multiple levels of analysis in the PBM, difficulties encountered by a strict Simonian approach to scientific reasoning are averted. We conclude that cognitive-historical explanations may benefit from PBM analyses.

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