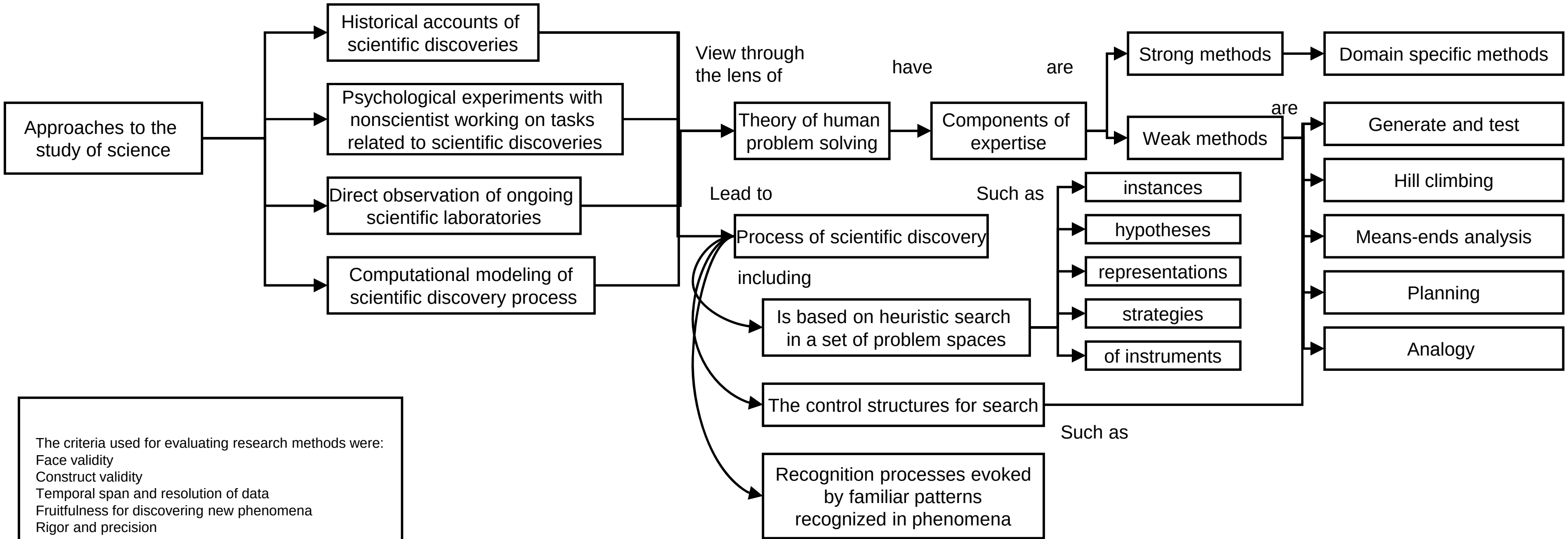
Klahr, D. & Simon, H.
Studies of scientific discovery: Complementary approaches and convergent findings
Psychological Bulletin, **1999***, 125*, 524-543



The criteria used for evaluating research methods were:
Face validity
Construct validity
Temporal span and resolution of data
Fruitfulness for discovering new phenomena
Rigor and precision
Control and factorability of variables
External validity
Social and motivational context

Approach	Description	Data collection method
Historical accounts of scientific discoveries	Aim at describing the cognitive and motivational processes of persons who have made major contributions to scientific knowledge	Are based on analyses derived from diaries, scientific publications, autobiographies, lab notebooks, correspondence, interviews, grant proposals, and memos.
Psychological experiments with nonscientist working on tasks related to scientific discoveries	Observe people's problem solving processes in situations crafted to isolate one or more essential aspects of real-world science.	Observation. Typically carried out in the psychology laboratory under the standard rubrics of experimental design with experimental and control conditions and the use of statistical significance test.
Direct observation of ongoing scientific laboratories	Study scientists as they "do science". It requires the trust and permissions of the scientists. The observer must be well versed in the domain of investigation to understand deeply what is happening and what the fundamental issues, problems, and solutions are.	The observer records the important activities of a day-to-day lab meetings, presentation, pre- and post-meeting interviews, lab notes and paper drafts. The raw data re then coded and interpreted within the framework of psychological constructs.
Computational modeling of scientific discovery process	A theory of scientific discovery process can sometimes be cat in the precise terms of a computational model that simulates these processes and re-enacts discoveries. The goal of such a model is to replicate the key steps in the cognitive processes of scientists as they made important discoveries.	

Convergent evidence of Principles of Discovery	
Principle	Discussion/Description
Surprise	A surprise calls for an explanation. That is, the observed phenomena was unexpected and unpredictable from the knowledge scientist hold. In cases of surprise, the phenomenon led to a hypothesis, rather than a hypothesis to experimental phenomena (p. 537) Surprise can only occur when expectations that have been formed are violated. In observational studies and exploratory experimentation, phenomena are, from time to time, recognized as conflicting with previously stored knowledge and expectations about the problem domain. In the face of surprise, scientist frequently divert the pat of exploration to ascertain the scope and import of the surprising phenomenon and to determine its mechanism. (p. 537)
Role of analogy and recognition.	Analogy can be viewed as a complex form of recognition and it is often the method of choice for formulating initial hypotheses and experiments in a variety of discovery contexts. (p. 537)
Multiple search spaces	Search in the hypothesis space .- generating new hypotheses in a type of problem solving in which the initial state consists of some knowledge about a domain, and the goal state is a hypothesis that can account for some or all of that knowledge in amore concise or universal form. Once generated, hypotheses are evaluated for their initial plausibility. Expertise plays a role here, as participants' familiarity with a domain tends to give them strong biases about the plausibility of hypotheses. Plausibility, in turn, affects the order in which hypotheses are evaluated: highly likely hypotheses tend to be tested before unlikely hypotheses (Klayman & Ha, 1987; Wason, 1968). Further more, participants may adopt different experimental strategies for evaluating plausible and implausible hypotheses. Search in the experiment space .- Hypotheses are both generated from and evaluated through experimentation. But it is not immediately obvious what constitutes a good or informative experiment. In constructing experiments, scientist are faced with a problem-solving task paralleling their search of hypotheses. However, in this case search is in a space of experiments rather than a space of hypotheses. If experiments are used to generate new information, then they should be designed to maximize the likelihood that they will reveal something of interest. If they are being used to tests hypotheses, they should discriminate among rival hypotheses. Data representation space.- representations or abstractions of the data are chosen from the set of possible features. What people search for in this pace is an effective and informative way to represent the phenomena they are observing. Here, as in many areas of science, finding the right representation is crucial, and it requires heuristic search, with all of the associated weak methods, in a large space of possibilities. One method for searching in the representation space that has attracted considerable attention is analogy. Search in the strategy space .- Changes in strategy, even while a fixed problem representation is maintained, may play an important role in discovery. Often the change in strategy results form, or leads to, the intervention of a new scientific instruments or procedures.

Klahar and Dunbar found that some participants (experimenters) focused on searching the space of possible manipulations, whereas other participants (theorists) focused on the space of possible explanations of the responses. Similar differences in preference between experiment-driven and theory-driven strategies have been noticed in other laboratory studies (Okada 1994, Okada & Simon 1997). Studies based on historical approaches can be interpreted in terms of the balance between hypothesis-space search and experiment-space search.