

Patterns and Effects of Analogies in Scientific Abduction

- A Remarkable Case of Creative Analogy -

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Introduction

The author investigates how scientists make spontaneous use of analogy in actual scientific abduction using an interview method. The purpose of the study is (1) to classify analogies used not in artificial settings but in actual scientific domains and (2) to report a remarkable case which has not been reported in the previous studies (Dunbar, 1994; Holyoak & Thagard, 1995).

Method

The interviews were designed to explore how scientists used analogy in abduction. The interviewees were 22 leading Japanese researchers in the fields of science and technology whose projects satisfied the following conditions: the research processes were recorded in detail, and the research had been completed or was in progress. The research records were examined by the project leader and the results of analyses were evaluated by other researchers, to verify their reliability.

Results and Discussions

Nineteen cases of analogy were reported. They were analyzed and classified into 3 types according to the similarity used: goal-directed, category-based, and category-formational analogy.

Goal-directed analogy is almost the same as purpose-directed analogy (Kedar-Cabelli, 1985), while category-based one is as regional analogy (Dunbar, 1994). In the latter analogy, there were 2 ways of deciding which knowledge of the source analogue was transferred: one is based on causality and the other is based on some meta-constraints, the latter of which has not been reported in detail.

In category-formational analogy, a source analogue was retrieved on the basis of a category like in category-based analogy, but the category used was the one extended from a pre-existing core category by adding some constraints. This type of analogy is important for creative thinking but has not been reported in detail: a typical but remarkable case is shown as follows.

Theme: To construct a theory which explains the unique behavior of a star cluster.

Situation before Analogy: There was a theory which aimed to explain the unique behavior of a cluster by regarding a cluster as an isothermal gas sphere such as a fixed star (*i.e.* the theory on the inner-structure of a star was the source analogue). However, most

researchers in those days recognized this analogy as a fallacy, since a cluster was considered to differ from a star in that the former is a discrete system whereas the latter is a continuous one. The concept of *self-gravitation* is established only in the star domain.

Analogical Reasoning: The researcher assumed that the unique behavior of a cluster was caused by the fact that a cluster is a self-gravitational system. He considered that if the assumption was right, not discreteness of a cluster but self-gravitation itself (*i.e.* the similarity) was the principal factor of the unique behavior. Hence he supposed that the theory on the inner-structure of a star would hold for the cluster domain. In order to take the effects of self-gravitation into account, however, the linear theory (on an isothermal gas sphere) had to be replaced by another theory (on a heterothermal gas sphere). So he introduced both the Prigogine's theory on non-equilibrium thermodynamics and the linearized stability theory, and at last succeeded in formulating the new concept of *selfgravo-thermodynamics*. He found that a cluster is quite similar to a star from the viewpoint, and transferred the theory on the inner-structure of a star to the cluster domain.¹

This analogy started from the pre-existing fallacious analogy. The new category *selfgravo-thermodynamics* was being formulated by extending the pre-existing core concept *self-gravitation* which had been misused as the similarity in the previous fallacious analogy.

Table 1: Classification of the cases reported (each figure denotes the number of the observed cases).

	causality-based transfer	metaconstraint-based transfer
goal-directed	10	0
category-based	3	4
category-formational	2	0

Summary

All the cases were classified, as shown in Table 1. Of the three types, the goal-directed analogy has the least possibility of mental leaps since it is close to deduction.

¹Then the transferred theory was partially modified based on thematic abstraction (Suzuki, 1994).