A THREE-PHASE DESIGN FOR PRODUCTIVE USE OF ANALOGY IN THE TEACHING OF ENTROPY

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ABSTRACT

Gentner has described analogy as a mapping of terms from a base (better known) domain to a target domain. She asserts that use of analogy can lead to new conclusions in the target domain. This 'structure mapping' theory, though useful, does not yet describe the process of analogical reasoning. We will argue that an analogy can be used productively in a process that has two phases: first, constructing the analogy using existing knowledge of base and target domains, and second, extrapolating the analogy within the target domain. In the first phase object mapping is motivated by the recognition of mappable relations. In the second phase, the productive use of the analogy can involve creation of both new terms and relations, as a result of mapping existing terms and relations from the base domain. If analogies are to be understood critically, then a third phase might be the testing of new relations against learners' experience. This three-phase process description of analogy has been tried out in a teaching experiment that aimed at an understanding of entropy, by an analogy to falling water. We conclude that this three-phase description is useful.

1. INTRODUCTION

The ability to think in analogies is believed to be central to human cognition. It is thought to play an important role in scientific reasoning, as well as in guided learning processes (Kurtz, Miao & Gentner, 2001; Baker & Lawson, 2001; Glynn & Takahashi, 1998). Research into the use of analogies in teaching can be roughly divided into two categories: according to whether the analogy is primarily seen as a tool used by the teacher to convey new concepts or information, or as a tool used by the students in drawing conclusions that are new to them. We would regard Glynn's (1989, 1998) "teaching with analogies" model and Zeitoun's (1984) "general model of analogy teaching" primarily as tools for the teacher in conveying concepts or information. In testing the effect of analogy, correct "recall" is the primary measure of success (Glynn & Takahashi, 1998; Arnold & Millar, 1996). Alternatively, theories developed by Gentner (1983) and Gick & Holyoak (1983), as well as Clement's (1993) and Brown's (1993) "bridging analogies", are about analogies as tools in the hands of the learner for solving problems, or reaching new conclusions about the target concept.

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Most authors from the last mentioned group describe analogy as a relation between "situations", or representations of situations, while in earlier publications Gentner (1983) clearly describes analogy as a relation between two propositional networks both of which already contain generalized statements about, for instance, electricity or the planetary system. In Gentner's later publications (Gentner & Holyoak, 1997; Kurtz, Miao & Gentner, 2001) concrete situations return as a basis and target for analogical reasoning. We agree that both definitions (relation between situations or between networks of propositions) may be of use in education, but they both apply to different phenomena. In this work we define analogy as:

> *a one-to-one mapping of terms between two domains of experiences that are each already described by networks of (generalized) propositions, the base domain, and the target domain, about which students want to draw conclusions.*

We chose this definition because the learning process that we were aiming at seems to demand working with generalised propositions. Another example seems to be the teaching of laws of electricity, starting from experiences with flowing water, where it was noted that first the base domain needs to be understood in terms of generalised propositions[1], before successful mapping to the target domain can be realised (Haeberlen & Schwedes, 1999; Gentner & Gentner, 1983). We therefore chose Gentner's (1983) "structure mapping" theory as our point of departure.

In the original version of this theory, the process in which an analogy is used to draw new conclusions could not be adequately described. The theory only describes the structure of a finished analogy, not the development of analogical reasoning in the course of time. More recently, it was asserted that:

> The process of analogical thinking can be usefully decomposed into several basic constituent processes. One or more relevant analogs stored in memory must be accessed. A familiar analog must be mapped to the target analog to identify systematic correspondences between the two (...). The resulting mapping allows analogical inferences to be made about the target analog (...). These inferences need to be evaluated and possibly adapted to fit the unique requirements of the target. (Gentner & Holyoak, 1997).

However, this "decomposition" does not yet give us a time sequence for use in education. Kurtz, Miao & Gentner (2001) recommend the detailed study of the processes that make up analogical reasoning as a direction for future research.

In this study, we test the following three-phase description of the process of analogical reasoning, for its usefulness in organising a learning process:

0) Learners study base and target domains separately for sometime.

[1] For example, "water is divided at branching points" and "the water is not jammed in our water circuits".