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Reconsidering Spontaneous Analogical Reasoning through the Knowledge in Pieces Mechanism

FOTOU Nikolaos (1), ABRAHAMS Ian (2)

University of Lincoln, School of Education, United Kingdom (1)
University of Lincoln, School of Education, United Kingdom (2)

Abstract

Much of the science education literature on analogical reasoning points to the benefits of analogies in helping students familiarize themselves with concepts, phenomena and situations they find abstract and difficult to understand. The conceptual benefits from such a use of analogies seem increasingly clear, as there is evidence from studies in which students were provided with an analogy, were taught how to use and, as a consequence, reached a better understanding of the concept, phenomenon, or situation they were unfamiliar with in the first place. This paper does not contradict the efficacy of such a use of analogies, but shifts attention to students' spontaneously self-generated analogies, as opposed to taught analogies where students do not generate the analogy but are asked to use and reason with. It discusses how the 'knowledge-in-pieces framework', according to which knowledge is viewed as a complex system composed of fundamental knowledge elements that are activated in response to a particular situation, can be used for viewing the relationship and interaction of students' knowledge with their spontaneous analogical reasoning. Data are drawn from small focus group discussions in which students of the same age group (9-10, 11-12, 12-13, 14-15, 16-17) were asked to explain predictions they made when presented with novel situations they had not seen before. The role of students' spontaneous analogical reasoning in these explanations is examined along with the knowledge they drew upon in order to make their predictions. The findings underscore the need to consider students' analogical reasoning and how their existing knowledge affects this reasoning which, in turn, impacts on their understanding of unfamiliar situations and phenomena.

Keywords: *Spontaneous Analogies, Knowledge-in-Pieces, P-prims, Analogical Reasoning;*

1. Introduction

Analogical reasoning -the cognitive process of drawing similarities between domains, often between prior knowledge and novel situations considered for a very first time- has been suggested as a key process in human cognition [1] and an important factor in learning at all ages [2]. It is for these reasons that analogies, as tools for instruction, have been of interest to educators and philosophers ever since Aristotle, with extensive research in this area consistently suggesting that analogies can play a significant role in students' learning and facilitate the teaching of abstract concepts, like those involved in science education [3].

Reasoning on the basis of analogies allows students to draw relationships between domains (situations, objects, concepts, etc.) they are already familiar with and unfamiliar ones they have never experienced before. It enables students to extend their existing knowledge from the familiar domain (base) to the unfamiliar (target) even if the two domains differ in many respects, and draw, in this way, inferences, albeit potentially erroneous ones [4], from the former to the latter. For example, when young students are asked to think about how plants grow, some spontaneously extend their existing knowledge that they themselves need to eat food to grow erroneously to plants and, as such, generate the erroneous belief that plants 'take up their food with their roots – rather than understanding that plant make their food through photosynthesis [5].

Therefore, reasoning on the basis of spontaneously generated analogies can, in some situations, result in the generation of misconceptions, depending upon the appropriateness of the base analogy selected which, in turn, is influenced by the existing knowledge of the person – experts are more likely in this respect to recognise an appropriate base domain from which to draw an analogy than is a novice..

1.1 Prior research on analogical reasoning

Analogies and analogical reasoning have been studied using a wide variety of research methods and from a wide range of perspectives. Much of this research has examined the effectiveness of an analogy in terms of the degree to which students can transfer knowledge from a base domain they are

provided with to a specific target domain and whether the similarities drawn from the one to the other lead to a scientifically correct inference to be drawn [6] [7]. Although the efficacy of such use of 'teacher provided' analogies finds support from that research, this paper considers the use of students' spontaneously, self-generated, analogies. The paper attends specifically to the interaction of students' prior knowledge with the analogical reasoning process through the Knowledge in Pieces (KiP) mechanism, where the term mechanism here is used to refer to the way a person reasons about and explains phenomena [8].
The following section presents a brief description of the KiP mechanism which is then used to interpret two students' analogical reasoning in a novel situation (situations they have not considered before being asked to make predictions about).

1.2 Knowledge in Pieces Mechanism

The KiP mechanism is based upon a Piagetian [9] constructivist tradition in which reasoning is perceived as a process of interpreting phenomena through existing knowledge. From a KiP mechanism, a person possesses a fragmented collection of independent, disconnected, knowledge elements named phenomenological primitives, or p-prims for short. P-prims are phenomenological in the sense that they are minimal abstractions, derived from experiences and closely tied to familiar phenomena, and are primitive in the dual senses of not needing further explanation and being evoked as a whole [8]. It is through p-prims that a person is enabled to explain and predict situations observed in the real world in a way that is consistent with the everyday lived experiences that these p-prims were abstracted from. In this reasoning process of explaining and predicting events, p-prims are activated only when the configuration of the contextual features of the situations under consideration fits the circumstances in which these p-prims originated [10].

2. Methodology

The paper builds on previous research [11] in which a total number of 166 students, from five different age groups (9-10, 11-12, 12-13, 14-15, 16-17), were provided with six novel situations. In these novel situations students were asked to make a prediction about the outcome of a future event (effectively what would happen in the event depicted in the novel situation) and then write or discuss, during focus groups, what led them to their predictions. The novel questions were all presented in a pictorial form so as to be accessible across this wide age range and also to avoid providing any kind of lead in terms of the selection of one particular option from those listed in the accompanying multiple-choice question.

3. Results

The analysis of students' responses in the questionnaire and the transcribed focus group discussions showed that their spontaneously generated analogical reasoning pervaded their thinking in making their predications and affected their understanding of the novel situations. Consider, for example, the responses given by a 12- and a 15-year-old student respectively in the weight and gravity novel situation (Figure 1) set out to probe students' understanding of the concept of gravity in conjunction with falling and weight.

> *I have answered B. It is the one under the box with the elephant [bulb A] that has to switch on first because it has greater mass than the other. If you cut the ropes then both boxes will fall and the one with the greater mass will fall down first. This is like holding a stone and a small marble in your hands and if you let them go, the stone will go faster. It always go faster because the weight is greater.*

> *In my opinion bulb A will switch on first, because the left box has greater mass than the right and therefore it should fall down first. I think that this is like the example in which we let a dumbbell and a ball from a roof to fall. Once let, the dumbbell hits the ground first*.

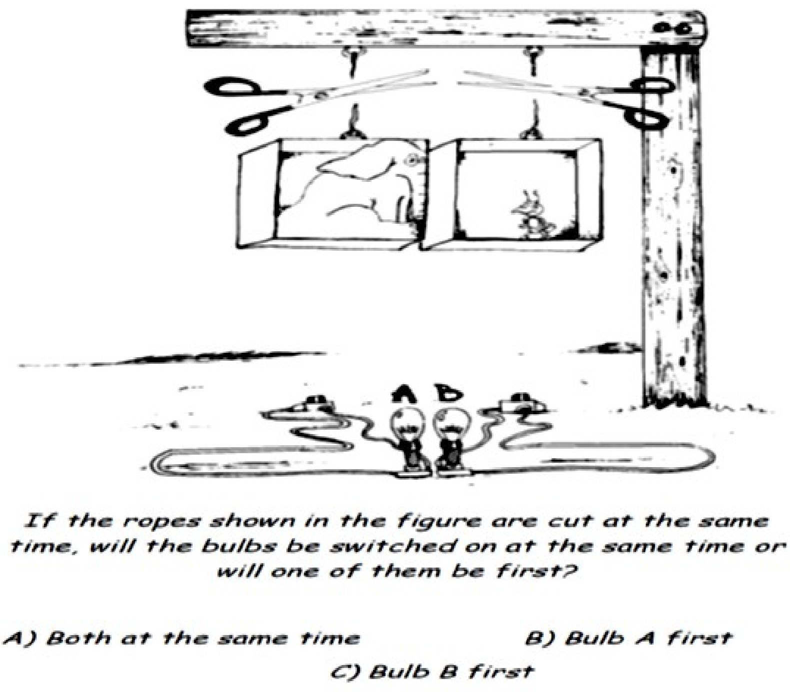

Fig. 1. Weight and gravity novel situation

From the KiP mechanism, p-prims are activated either alone or in combination with the analogies. In the above example when students see that the rope is cut the first p-prim that was found to be frequently activated was the 'supporting p-prim', according to which objects need to be supported in order not to 'fall downwards' [9]. Once this p-prim is activated, and students think of this situation as being analogous to their everyday observations of objects falling towards the ground, the next p-prim that was often observed, from their discussions, to be activated was the 'Ohm's p-prim' [9], according to which the stronger the agency the greater the effect. In this example the agency is the weight of the two objects, and by seeing this situation as analogous to one where two objects of different mass are set to fall downwards, the activation of the Ohm's p-prim leads students to the inference that the heavier object, in this case the box with the elephant, falls to the ground first.

5. Discussion

The results showed that students' analogical reasoning was dependant on the p-prims evoked by the novel situations (target domain). Once activated, the role of the p-prims was to provide a basis for the student to make comparisons between the base and the target domain [12] while the role of analogies was to drive the application of inferences from the one to the other. Many of the analogies students spontaneously self-generated were very similar and, in some cases, identical with those suggested [8] to be the sources of p-prims in the KiP mechanism.

The findings underscore the need to consider students' analogical reasoning and how their existing knowledge affects this reasoning which, in turn, impacts on their understanding of novel situations and phenomena and can often lead them to misconceptions. This could help in further examining the role of the knowledge students bring with them to learning events, in and outside the science classroom, and how this knowledge is likely to affect their ongoing reasoning which, as the study showed, is often influenced by their use of spontaneous, self-generated, analogies.

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