Analogical Concept Formation in Scientific Explanations

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In philosophy of science concept formation is usually discussed with respect to definability. In my paper I'm going to expand this discussion to concept formation with the help of analogies.

Analogies are frequently used in scientific explanations and descriptions for concept formation (cf. Schurz, 2008). Indicators for analogical reasoning are comparing phrases like 'similiar as', 'likewise' and 'analogically'. A prototypic analogy that is discussed often in philosophy of science is that one established between concepts of fluid physics and concepts of electromagnetism: in order to explain some concepts of electromagnetism often interrelations between these two different areas are stressed. So, e.g., one can describe potential difference by the help of pressure difference in a pipe filled with liquid. The characterization would be:

> Potential difference between two ends of a conductor is analogical to pressure difference between two ends of a pipe filled with liquid.

Of course this analogy is no complete characterization of 'potential difference'. E.g., it holds with respect to the law of Hagen-Poiseulle and Ohm's law:

> (L1) Ohm's law: v_1-v_2=I/k
> (L2) Law of Hagen-Poiseulle: p_1-p_2=V/c;
> (where: p_i ... 'pressure' can be mapped to v_i ... 'potential', V ... 'water volume in the pipe (relativized to a time segment)' can be mapped to I ... 'amperage' and c ... 'liquid speed' can be mapped to k ... 'conductance')

But it doesn't hold with respect to the proportions between volume/amperage and radius of a pipe/conductor:

> (L3) $V \sim r^4$, whereas:
> (L4) $I \sim r'^2$
> (where: r ... 'radius of the pipe' is mapped to r' ... 'radius of the conductor')

Because of this fact Carl Gustav Hempel allowed analogical concept formation only with respect to a relativization to the relevant coinciding regularities (cf. Hempel, 1970, sect.6):

> Potential difference between two ends of a conductor is analogical to pressure difference between two ends of a pipe that is filled with liquid with respect to the laws of Hagen-Poiseulle (L2) and Ohm (L1).

Analogical usage of language about two different domains (e.g., physics of liquids and electromagnetism) is given in our example in the sense that some descriptions of

regularities are invariant under a syntactical isomorphism, that is: *V* is mapped to *I*, *c* is mapped to *k*, p_i is mapped to v_i and vice versa and the regularities described in L1 and L2 are invariant under such a mapping.

More technically speaking, one can define a mapping *is* on the vocabulary of both theories in such a way that:

- $is(I) = V,\ is(V)=I$
- $is(v_i) = p_i,\ is(p_i)= v_i$
- $is(k) = c,\ is(c)=k$

Then one may generalize *is* inductively:

- For all $P^n, t_1, ..., t_n : is(P^n(t_1, ..., t_n)) = is(P^n)(is(t_1), ..., is(t_n))$
- For all terms $t_1, t_2: is(t_1 \equiv t_2)=is(t_1)\equiv is(t_2)$
- For all formulas $A: is(\sim A)=\sim is(A)$
- For all formulas $A, B: is(A\&B)=is(A)\&is(B)$
- For all formulas *B* and variables $x: is(AxB)=Axis(B)$

And claim, by establishing a relation of analogy, that some descriptions of regularities of the theories are invariant, and some other such descriptions are not invariant under the isomorphic mapping *is*: L1→*is*(L1)=L2, and not: L3→*is*(L3)=L4.

But what does it mean that by these analogical relations current (*I*) and conductance (*k*) are in some way characterized? Since the analogical relation (L1→*is*(L1)) can be restated logically equivalent as:

$$L1 \rightarrow (is(L1) \leftrightarrow L1)$$

one may see in such a characterization of *I, k* and v_i a characterization with the help of conditionalized contextual definitions of *I, k* and v_i. Of course, such a view bears some very relevant problems:

- What is it to give a conditionalized multiple characterization of an expression?
- What are the differences between contextual definitions for concept formation and non-definitional axioms?

In my talk I'm going to elaborate the above sketched view on concept formation by analogies a little bit more and try to indicate some satisfying answers to the two formulated main problems. Since concept formation by analogies is actually not much discussed in philosophy of science and since a solution of the main problems mentioned here seems to be best discussed in the framework of theory and concept reduction, I will also present some very interesting relations between analogical concept formation and the much more discussed area of concept reduction (where to reduce a set of concepts C_2 – e.g., some concepts of psychology – to another set of concepts C_1 – e.g., some concepts of physics – is to relate all concepts of C_2 in a specific way to those of C_1).

Hempel, C. G. (1970). Aspects of Scientific Explanation and other Essays in the Philosophy of Science. New York: Free Press.

Schurz, G. (2008). "Patterns of Abduction". In: Synthese 164.2 (2008), pp.201–234.