Could philosophy inform biology education?

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ABSTRACT

This paper reports on the rationale of a study that aims at exploring whether philosophical theories of concept formation can inform biology education. Thus, we will first summarize some basic philosophical theories that try to explain how humans form concepts like ANIMAL, FISH, etc. And then, we will suggest that such theories can help us design learning environments to promote rigorous mechanisms of concept formation and facilitate young children in the classification of living organisms and the construction of a more meaningful understanding of the biological world.

KEYWORDS

Concept formation, philosophy, biology education, classification of living organisms

RÉSUMÉ

Cet article rend compte d'une étude qui vise à explorer en quoi les théories philosophiques sur la formation des concepts peuvent aider à l'enseignement de la biologie. Nous allons, dans un premier temps, explorer les principales théories philosophiques pouvant expliquer comment les humains forment des concepts comme ANIMAL, POISSON, etc. Dans un second temps, nous proposerons des pistes pour que ces théories puissent nous aider à créer des environnements d'apprentissage favorisant la formation de concepts et faciliter la classification des organismes vivant chez les jeunes enfants dans la perspective d'une meilleure compréhension du monde biologique.

MOTS-CLÉS

Formation des concepts, philosophie, éducation de biologie, classification des organismes vivants

INTRODUCTION

In this paper we present the rationale of a study that will be performed in order to explore whether philosophical theories of concept formation can inform biology education. The study will be concerned with whether it is feasible to design a learning environment in the context of biology that could support the transition of primary school children from early and more intuitive mechanisms of concept formation to more sophisticated and rigorous ones, all described in relevant philosophical theories. So, here we will (a) summarize some basic philosophical theories on concept formation that try to explain how humans form concepts like ANIMAL, FISH, etc., and (b) we will suggest that such theories can help us design learning environments that could promote rigorous mechanisms of concept formation and facilitate young children in the classification of living organisms. We will focus mainly on (a) the prototype theory and (b) the classical theory, for we believe that these two theories better describe the progression from more naive to more advanced - or *scientific* - concept formation mechanisms. These two theories can help us review a continuum from (a) *how we categorize* to (b) *how we ought to categorize*, and thus help us design a learning environment to facilitate primary school children move from the one end of this continuum to the other.

PHILOSOPHICAL THEORIES OF CONCEPT FORMATION

How do we categorize the world into concepts? That is, how do we decide which objects to put under concepts such as MAN, CAT, ANIMAL, PLANT etc.? Plato and Aristotle debated strongly on the subject and the debate still holds in philosophy, with serious implications about how we learn things in general. Human concept formation mechanisms build mental categories and make taxonomic classifications of these categories that enable us to understand, remember, explain or teach all kinds of things about the world. If we had to have a name for each individual object or event, it might be impossible to recall or use all this information to build any kind of theory about the world. Given our concept formation ability however, we do not need to talk about every single cat; we can refer to CATS in general; put CATS into more general concepts, such as MAMMALS, ANIMALS or LIVING THINGS. Thus, we can recognize objects quickly, talk about their similarities and differences, recall old or learn new information, reason about their properties, solve problems, speak a language and understand other people quickly. Our concept formation is vital for all our endeavors. Starting from philosophy then, the question of *how we form concepts* is a matter of debate in cognitive science, psychology or science education for more than 50 years now.

So, currently there are roughly four general categories of concept formation theories – that is, of *how we understand or learn which x to put under concept C.*

1. *Definitionism or classical theory*. We categorize individual objects or events into general concepts by logical analysis, namely articulating definitions that describe the necessary and sufficient conditions, which must be fulfilled in order for an instance x to be classified under the concept C. For example, in order to say that John is a BACHELOR, John would have to be an unmarried man in marriageable age. Humans use inductive and productive reasoning skills to decide if a certain instance (e.g. John) belongs to a certain concept (e.g. BACHELOR) in terms of necessary and sufficient conditions. This theory is as old as Plato, but still has many followers (Pitt, 1999; Peacocke, 2000; Earl, 2006). One objection to this theory is that most concepts can hardly be defined fully and unanimously. Plato already suggests so for philosophical concepts like KNOWLEDGE, GOOD, ETHICS, etc. Today empirical evidence shows that very rarely we use necessary and sufficient conditions in order to form categories (Laurence & Margolis, 1999; Murphy, 2002; Prinz, 2002). Thus, there have been more moderate versions of classical theory that roughly suggest that, even though we cannot always define the concepts by both necessary *and* sufficient conditions, we *do* look

for (a) necessary, *or* (b) sufficient conditions. The appeal of this theory is that it describes a solid reasoning mechanism for concept formation; a mechanism that can provide us with lucid concepts and clear criteria for the inclusion of a certain instance x under a concept C (e.g. ANIMAL, GENE, etc.). And even though empirical research shows that we rarely use such solid rezoning mechanisms for concept formation, one could argue that this is the way we *should* form concepts at least in science; and also one may argue that this is what science and scientists try to do: articulate clear definitions for scientific concepts.

2. *Family resemblance theory* or *prototype theory* or *exemplar theory*. These are all versions of the same idea Wittgenstein suggests in his *Philosophical Investigations* (1958). His most typical example is the concept GAME: many different activities from chess to basketball are considered GAMES. The term cannot have a clear cut definition. What such activities have in common is a very loose similarity among them. According to the idea of family resemblances then, we classify instances of activities or events under certain concepts, by making a rough, intuitive analysis of their similarities. Thus, we classify an object x under concept C if it shares many similarities with other objects z, w, etc., which we have already included in C. From this general idea of family resemblances two more versions of this theory came up. (a) The *prototype theory* is the more rigid one, and suggests that we have some mental prototype or typical example for each concept, and we use it as the standard by which we compare and classify all new instances. For example, I have my dog as a prototype ANIMAL and I use this to decide whether any novel things I see (cats, mice, birds, telephones, etc.) share enough similarities with my dog to qualify as ANIMALS. (b) The *exemplar theory* is a softer version. According to this, we recall random examples of some concept C, and use them to decide whether a new, target instance qualifies as C. All versions of the theory have followers today, both in philosophy and in other disciplines and there are also some empirical tests for them (Rosch & Mervis, 1975; Rosch, 1978; Osherson & Smith, 1981; Smith & Medin, 2002; Bennett & Hacker, 2008; Kenny, 2010). Yet, even though we probably form concepts by relaying to family resemblance, this theory has major problems. It is not clear what kind of entity is the prototype; or what kind of similarities we draw upon; or even how we identify that very similarity (Fodor, 1998; Laurence & Margolis, 1999). Additionally, some concepts don’t seem to have a prototype or any examples at all, e.g. negative concepts like NOT A CAT (Laurence & Margolis, 1999). Other concepts are considered prototypes even though there is nothing typical about them. E.g. most people consider number 3 a more typical instance of an ODD NUMBER than 7, and 7 more typical than 501 (Armstrong, Gleitman & Gleitman, 1999), but this is not valid. Furthermore, this theory does not satisfy the *principle of compositionality* by which *the meaning of a complex expression is determined by the meanings of its constituent expressions and the semantic and syntactic rules used to combine them*. So, if for example we form the concept PET FISH bearing in mind an exemplary pet fish, this complex concept will have properties (e.g. colored, tropical, etc.), which are not necessary inferred from the properties of synthetic categories, namely PET and FISH (Fodor, 1998; Hampton & Jönsson, 2011). Due to these problems, even if this theory might explain how we intuitively use concepts in everyday practices, it cannot explain how we form scientific concepts (Keil, 1989; Gelman, 2003). More importantly, it *should not* qualify as a mechanism for scientific concept formation.
3. *Theory-theory*. We classify individual appearances of objects under certain concepts understood in the context of a theory of related phenomena. The theory by which we include an object under a certain concept may either be naive and intuitive or more scientific, depending on our age, education, background etc. For example, a child might use an intuitive

theory by which they classify certain items as ANIMALS, PLANTS, FISH etc. After a while, and as their theoretical understanding changes, they will also modify these concepts so that the FISH can also qualify as an ANIMAL. The theory-theory has many versions as well. What is common to all is that a concept is always considered attached to a theory and is defined in relation to the other concepts of the theory, so that the latter is coherent both n its own and with the overall fabric of our beliefs. The origins of this theory are found in the writings of Quine (1960) and Kuhn (1962), but the theory-theory is continuously elaborated to date (Keil, 1989; Gopnik & Mertzoff, 1997; Murphy 2002; Carey, 2009). When it comes to concept formation mechanisms however, theory-theory usually falls back to the problems described by the prototype-theory and / or the classical theory. We identify similarities and differences based on typical examples or based on definitions *within the context of a theory* (Markman, 1991). These definitions may change when new info comes to light. The theory-theory, therefore, can operate as an "umbrella" for theories 1-2; it has been already introduced in science education, to explain the revision of concepts (conceptual change) taking place in education (Chi & Roscoe, 2002; Inagaki & Hatano, 2002; Chi, 2008).

4. *Atomic theory or theory of conceptual atomism.* We classify individual instances under a certain concept C, detecting the *reference* of the concepts C in the real world. By *reference* here we mean all the things designated by the concept. The reference of the concept CAT, for example, is the actual cats that exist in the world. So, whenever we use the concept CAT, we aspire to refer to what is really unique and common to all the cats, the real essence of *cat-hood* so to speak, regardless of what we - or the scientific community - know today about cats (Kripke, 1972; Putnam, 1975; Milikan, 2000; Fodor, 1998, 2008). This theory has many versions, as well as significant problems that arise from its strong ontological commitments about what a concept really is.

PHILOSOPHICAL THEORIES OF CONCEPT FORMATION & BIOLOGY EDUCATION

Theories 1-4 are not mutually exclusive; in fact, it is likely that different types of concepts are formed differently, or that different people or communities categorize differently. However, since our aim is to explore whether biology education can be informed by these theories, we will not get into the atomic theory at all. We believe that this theory encourages *essentialism*, an intuitive reasoning device through which entities are classified in the same category based on the idea that they all share a common, inner unchanged *essence* (Gelman, 2003); in other words, it encourages a reasoning device that should be gradually replaced with more sophisticated ones. On the contrary, we *do* believe that theories 1-3 could inform biology education in one way or another.

Prototype theory describes intuitive mechanisms of concept formation and it seems to be supported by empirical data as well (Rosch & Mervis, 1975; Rosch, 1978; Smith & Medin, 2002). The objections to this theory however, suggest that these mechanisms are extremely fallible. We form categories comparing examples, building prototypes or using features of the prototype as sufficient conditions, on the basis of random similarities. Intuitive concept formation then hardly relies on robust criteria (Bishop & Trout, 2005), while building scientific concepts *does* need them. Since science education is engaged in promoting scientific culture and rigorous thinking in general, it should discourage the persistence on such mechanisms and eventually lead to their replacement by more advanced. On the other hand, more advanced mechanisms are described by *classical theory*. In fact, this theory describes by far the most rigorous concept formation mechanisms even though it seems that we don't much use them spontaneously. It also includes a visible progression: we can construct definitions (a) by sufficient conditions, (b) by necessary conditions, and (c) by necessary and sufficient conditions. Finally, *theory-theory* can be combined with both the above theories: a general theory about the living world could function as a framework either for prototyping or for constructing definitions. It is worth investigating then, whether the context of a theory can facilitate the progression of children's concept formation mechanisms.

It is worth noting that while all these theories are explored in philosophy, psychology and cognitive science, they have not been much used in science education. And insofar as they have, engagement was merely descriptive, just aiming to verify whether children do in fact use mechanisms described by certain theories. We believe however, that the key challenge for science education is not to describe how children form concepts, but rather to help them familiarize with *rigorous* concept formation mechanisms, which could result in well-defined concepts that promote scientific understanding. This is what we actually plan to attempt by utilizing *prototype theory* and *classical theory* and setting focus on young children's biological understanding in particular. In summary, we believe that (a) *prototype theory* best explains children's intuitive mechanisms of concept formation, (b) *classical theory* - lying at the other end of the spectrum - suggests rigorous concept formation mechanisms, at least for science education purposes, and (c) *theory-theory* might possibly facilitate the activation of concept formation mechanisms that both these theories suggest.

Therefore, we plan to develop and test a biologically oriented learning environment that could possibly support the transition of primary school children from early concept formation mechanisms described by *prototype theory* to more sound and robust ones described by *classical theory*. The research question of our case study will be *'Can we help children advance their categorization devices within an appropriately designed learning environment in the context of biology and how?'; 'Can we help them move (a) from examples of a concept to a prototype, (b) from a prototype to a definition with some sufficient conditions, and (c) to a definition with some necessary conditions?'.*

Young children have a particular interest in entities and phenomena of the biological world and they start to use and form biological concepts very early (Inagaki & Hatano, 2002). Biology gives us a wide range of options to work with: from everyday language concepts (e.g. ANIMAL) to scientific ones (e.g. NUCLEUS). Moreover, it can give us plenty of room to invent imaginary categories (e.g. categories of imaginary animals with imaginary properties) that could be used in learning activities, since, even if they do not exist, they can be intuitively understood and used for reasoning by children (Lawson, 1995).

The development of concept formation mechanisms is an important step for science education, because it facilitates children to engage in meaningful learning processes and get familiar with science culture as well. It is also an important step in a more general sense. It facilitates the classification of all the information children learn, so that they can remember it and use it more adequately. And last but not least, it can contribute to context-free rigorous thinking; after all, the basic tool of human mind *is* concepts.

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