Conceptual Coherence in Philosophy Education - Visualizing Initial Conceptions of Philosophy Students with Self-Organizing Maps

Anna-Mari Rusanen (anna-mari.rusanen@helsinki.fi)
Philosophy of Science Group, Department of Philosophy, PO BOX 9
00014 University of Helsinki, FINLAND

Otto Lappi (otto.lappi@helsinki.fi)
Cognitive Science Unit, Department of Psychology, PO BOX 9
00014 University of Helsinki, FINLAND

Timo Honkela (timo.honkela@tkk.fi)
Adaptive Informatics Research Center, PO BOX 5400
FI-02015 TKK Helsinki University of Technology, FINLAND

Mikael Nederström (mikael.nederstrom@psycon.fi)
Department of Psychology, PO BOX 9
00014 University of Helsinki, FINLAND

Abstract

We present a framework for research on coherence of student conceptions in philosophy education. Commonsense conceptions of philosophical novices were studied. Students of a Finnish upper secondary school with no prior background in philosophy were asked to evaluate statements on conceptual issues in the domains of philosophy of mind, metaphysics and epistemology. The results were visualized with Kohonen self-organizing- maps (SOM), enabling us to identify clusters of students and questions with similar response patterns. The results are interpreted in terms of students' ontological commitments.

Keywords: Conceptual change; commonsense conceptions; philosophy of mind; self-organizing maps.

Introduction

Most students have an intrinsic interest in philosophical problems. They spontaneously develop their own conceptions, arguments and theories about various philosophical issues, including metaphysical and ontological questions about the nature of mind. What is known of these students' ideas of philosophical problems? What are the crucial cognitive and metacognitive operations required to comprehend philosophical content? What are the student characteristics enabling them to - or hindering them from – developing coherent philosophical viewpoints and sustained arguments on philosophical topics?

This paper has two main foci. We outline a framework where the empirical research of conceptual organization of philosophy novices could be placed, and we also present the results of our own preliminary empirical research along these lines.

The general theoretical approach of this study is based on the conceptual change paradigm. According to it the starting point of the learning process are the commonsense theories people have developed prior to instruction, and the outcome of successful learning is internalization of a philosophical theory or a worked-out philosophical position on the issues.

There is a large body of research which shows that novices conceptions do differ from those of experts', but researchers still remain divided not only about the nature of those differences, and also the status of novices' belief systems. Some researchers claim that novices belief systems are weakly organized systems that are internally inconsistent, piecemeal and incoherent (diSessa, 1993). Other researchers argue that novice belief systems are not only internally quite coherent but they may also share the essential properties of scientific theories (Chi, 1992; Samarapungavan and Wiers 1997; Vosniadou & Brewer, 1992).

In our empirical design we focused on the initial state of the learning process – the commonsense conceptions of philosophical topics students hold when they are first exposed to academic philosophy[1]. The aim of the study was to capture some features of philosophy novices' conceptual organization, and also to give us clues of the degree of their belief systems' coherence. In this paper, we will first take a brief look at the theories of conceptual change (section two) and then present our empirical research (section three).

Background: Conceptual Change and Philosophy, some Domain specific considerations

In the conceptual change paradigm, learning of scientific content is seen as a replacement of confusions and misconceptions or everyday commonsensical frameworks with new more sophisticated and theoretically deeper ones. This is taken to entail some kind of wholesale reconstruction of

[1] In Finland this occurs at the first year of upper secondary school.

one's theoretical outlook on a domain. In conceptual change the difference between the initial state and the outcome of learning is not merely accumulation of knowledge and rejection of false beliefs. Instead, the students' conceptions of phenomena in a domain undergo a holistic restructuring process, leading to acquisition of new (for the students) scientific concepts and a reorganization of the students' web of beliefs from a fragmented set of commonsense beliefs to a consistent web of scientific conceptions. (Carey, 1985; Strike & Posner, 1982; Vosniadou, 1992; Vosniadou & Brewer, 1992; diSessa, 1988, 1993; Chi, 1992).

In general, conceptual change is considered as a replacement of old, naïve conceptions with the new, more sophisticated ones. This replacement process is usually thought to require some sort of cognitive conflict, since there must be dissatisfaction with the existing concepts (Strike and Posner, 1982). Moreover, the process requires also an alternative conception that is intelligible, appears initially plausible and is believed to be a fruitful way to conceptualize the domain (Strike and Posner, 1982). In science education the domain of interest could be Newtonian motion or biological inheritance and evolution. The outcome would be then an understanding of the relevant scientific theories.

The assumption is that by confronting the belief system with real world counterexamples, the misconceptions - i.e. sources of confusion and incoherence in the commonsense picture - can be revealed. This kind of procedure reflects not only the basic methodological principles but also the explanatory aims of these experimental sciences. These sciences aim to describe the relevant causal or functional organization in the world (see Cummins, 1983, Bechtel & Richardson, 1993, Craver, 2006). Their theories and models are taken to represent the world in a sufficiently correct way. Moreover, these explanatory structures are also intended to help us to understand how the target system would behave under a variety of causal manipulations (Woodward, 2003).

In philosophy education the relevant domains and the outcomes of learning are somewhat harder to delineate. But it seems natural enough to consider traditional philosophical topics such as the nature of mind as domains, and well thought-out philosophical positions as the potential outcomes of learning. However, philosophy also uses its own method of inquiry - conceptual analysis rather that empirical investigation or formal proof – and as the method of theory formation differs from the method of theory formation used in the natural sciences. These special characteristics of philosophy should be taken into account when the learning of philosophical content matter is analyzed.

In natural science domains cognitive conflicts can be raised by contrasting and confronting the belief system with the counterexamples based on empirical data and observable phenomena in the real world. In contrast, philosophy aims to uncover tacit commitments, make precise ambiguous positions, and clarify the interrelationships between concepts and beliefs. In many cases, philosophical theories are not *about* the independently observable structure of the world at all. Consequently, in philosophy cognitive conflicts cannot be raised just by confronting the student's conceptions with observation or "the world". A parallel observation has been be made in the context of other educational domains, such as history. For instance, Limòn and Carraterro (1999) have pointed out that the domain of history allows methodologically an interpretation of historical events from different perspectives. Hence there is not one, correct empirical fact that could serve as a source of correct explanation.

In philosophy misconceptions are more or less purely *conceptual* confusions, inconsistent definitions, or logical fallacies. Philosophical examples and counterexamples are usually thought experiments interpreted, and then weighed against intuitions - the students own intuitions and the intuitions of philosophers putting forward and arguing for a specific theory.

Conceptual Organization and Coherence

There is a large body of experimentally based literature where it has been argued that the difference between the consistency or coherence of the belief systems of novices and experts is one of degree, not of kind. It has been proposed, for instance, that the novices "explanatory frameworks" are internally coherent, consistent, interrelated set of beliefs that are similar to kuhnian paradigms (Samarapungavan & Wiers, 1997). Also some researchers, such as Chi and her colleagues, argue that the belief systems of novices demonstrate conceptual coherence at the ontological level (Chi, 1992; Chi & Slotta, 1993; Slotta et al., 1995). According to Chi people assign entities to ontological categories, and depending on the category certain attributes may or may not be attributed to the objects. For instance, physical objects are assigned to the category of "matter" and assigned such attributes as "occupies space". Chi and her colleagues propose that this categorization system may offer a coherent basis for the conceptual organization of novices. In their account, ontological categories and the related attributes provide conceptual unity, and pre-theoretical coherence within domains, across situations.

However, there are researchers, who disagree with this "theory-theory" characterization of novices' belief systems. For instance diSessa (1993) describes novice knowledge as a weakly organized system of beliefs that is highly context dependent and internally inconsistent, thereby lacking internal coherence. In diSessa´s account commonsense physical knowledge is organized into p-prims, empirical typologies or low-level abstractions of everyday experience. Opposing this, Chi and others (Chi & Slotta, 1993; Chi, Slotta and deLeeuw, 1994) argue that novices responses to physical problems do in fact demonstrate conceptual coherence at the ontological level, even in cases where reasoning is guided by p-prims. Chi and Slotta (1993) suggest that ontological attributes - such as "occupies space" - may manifest themselves, in a coherent way, withiin p-prims - such as “blocking” - which are context specific descriptions of phenomenological situations.

All boils down to the notion of “coherence”. Conceptual coherence is the “glue” that holds concepts together in a web of belief (Murphy and Medin, 1985). There is, of course, a long tradition in cognitive science research on coherence. For instance, conceptual coherence can be defined as follows (from Thagard & Verbeugt, 1998, Thagard et al, 2002): (i) Conceptual coherence is a symmetric relation between the pairs of concepts, (ii) a concept coheres with another concept if they are positively associated i.e. if there are objects to which they both apply, (iii) the applicability of a concept to an object may be given perceptually or by some other reliable source, (iv) a concept incoheres with another concept, if they are negatively associated, i.e. if an object falling under one concept tends not to fall under the other concept. Finally (v) the applicability of a concept to an object depends on the applicability of other concepts.

Now, the empirical issue is, to what extent novice conceptions fulfill these conditions. For instance, if a novice uses the notions of “matter” and “non-material” in a coherent way, a novice should be able to formulate a correct positive association between concepts in cases where there are objects to which “material” and “non-material” both apply (i-iii) and also be able to distinct the cases when an object falling under one concept (“material”) do not fall under the other concept (“non-material) (iv). Now, the condition v implies that the applicability of a concept, such as “material” depends on the applicability of other concepts, such as “occupy space” etc. The challenge is to operationalize the notion of coherence in an empirical design. We present work in this direction.

Methods

To begin an investigation into students’ pre-instruction ontological categorizations and conceptual coherence in *meta*physics and ontology, we administered a multiple choice questionnaire on these topics to students of a large Finnish Upper secondary school for adults. The questionnaires were designed to include two sets of questions: one to probe the ontological commitments of the respondent, and one where the respondents were asked to suspend their ontological commitments and reason hypothetically. (The idea with the latter questions was to force the students to respond on the basis of their intuitive conceptual commitments rather than ontological beliefs per se). The students’ responses were coded in the binary format and fed into a Kohonen Self-Organizing Map (SOM). The SOM is a neural network that uses an unsupervised learning algorithm that can be used to visualize hidden statistical structure in the data, enabling us to demonstrate similarity groupings of questions and students for further analysis.

Subjects

The subjects (n=68, 38 male 30 female) were students of a large upper secondary school in the area of Helsinki. They had no previous background in academic philosophy. The age of the subjects ranged from 15 to 23 years (mean 18 years, s.d. ±2 years, median 18 years). All were enrolled in the first, compulsory philosophy course in the Finnish upper secondary curriculum, and had completed the Finnish comprehensive school. The students were of variable socioeconomic background and academic ability.

Materials

To obtain information on the students’ conceptions, we developed a multiple choice-questionnaire. The paper and pencil- questionnaire included 63 thematically selected items. This paper presents the results of three thematic sets of questions. These sets probe (1) the subjects’ ontological commitments with regard to the mind and the body, (2) hypothetical questions that relate to the possible spatial and temporal attributes of bodyless minds (3) hypothetical questions that relate to the possible perceptual and cognitive attributes of bodyless minds. Each of these conceptual subdomains was probed with multiple questions, and the students’ responses were examined, coded in the binary format and used to train a self- organizing map for visualization.

Data-analysis

The self-organizing map is an artificial neural network that uses an unsupervised learning algorithm as the basis of similarity comparisons. The SOM, in a nutshell, analyzes the hidden structure of the input data. More precisely, the architecture of a Kohonen self-organizing map can be summarized as follows (from Kohonen, 2001). It consists of a set of interacting adaptive processing elements, adaptive prototypes. They are usually arranged as a two-dimensional grid called the map. Every node of the map is connected to a common set of input. Any activity pattern on the produces a variable pattern of activity in the nodes, and the map is updated so that neighboring cells on the map are made more similar to the most active node (best fit to data item), which in turn leads to topological clustering on the map, reflecting recurring similarities among data items. The result is a map where similar inputs are placed close to each other, and dissimilar items further apart.

Since there is no need for a priori classifications of the input (the learning algorithm of the map is unsupervised) the map is a useful tool in exploratory data analysis and visualization. The map itself, however, provides to conceptual interpretation of the clusters nor a discrete partitioning of the inputs into classes of similar items, which need to be provided by the researcher interpreting the map.

Results & Discussion

Ontological Commitments

The first set of questions probed the basic ontological commitments of the students. Overall, it seemed that about 70% of our Finnish upper secondary school students were dualists of some kin. For instance, when they were assessed the claim "The mind is material", 73% answered "no", and when they were asked if the mind is immaterial" 69% answered "yes". However, this does not imply that 70% of the students would have answered the question on the basis of a coherent substance dualism. When they were asked if the human mind is an immaterial *entity*, only 50% of students found it to be so. How can these percentages be reconciled? It may be that either students have difficulties to understand the notion "entity" in a mentalistic context (fragmentation), or they may alternatively think that the mind is a sort of event or a process (ontological theory)[2].

A hierarchical cluster analysis using Ward's method on the first set of questions suggested the students might be divided into four categories. When the pattern of responses to these questions was analyzed qualitatively, a four category typology of responses types could be constructed, based on three diagnostic subsets of the questions (cf. Table 1). *Subset 1* (questions 2, 9, 10 & 18) asked if the mind is immaterial rather than material, *Subset 2* (14 & 37) asked if the mind has a material basis, and *Subset 3* (15, 20, 22 & 35) asked if the mind could exist without a material basis.

One group (A) mostly denies the immaterial and independent nature of the mind. These students are apparently some sort of materialists. Another group (D) has a diametrically opposing view: they consider the mind to be immaterial and, although many say the mind has a material basis, to be at least in principle independent of it. They therefore seem to be traditional dualists. A third group (C) considers the mind to be immaterial, but nevertheless dependent on a material basis for its existence. These students may be some kinds of dualists, or "emergentist" materialists. Finally, there is a fourth group (B), for whom we struggled to find any straightforward interpretation. It may be either that these students lack a consistent outlook on the ontology of the mind, or else the items on the questionnaire fail to probe it well enough. These alternatives are left as open questions for future research.

When the results of this set of questions were fed into a self-organizing map we could identify these types with clusters of students with similar overall response patterns (fig. 1). Looking at the map, we see that of the four groups of students group D ("dualists") form a well-defined cluster in the lower right corner of the map. Group A ("materialists") are located at the opposite (upper left) corner, and are also fairly nicely clustered. Group C ("emergentists") is located in the center, somewhat nearer the materialists than the dualists, and is more diffuse. Finally, members of group B are much more scattered throughout the map. This is the group for which we failed to find any coherent content-description. (It may be that with more subjects/items this group would divide into several).

[2] Students also seemed quite sensitive to the exact wording of the questions. For example, most students answered that a mind has a material basis, viz. the brain (91%), but when they were asked if the mind has a material basis but the brain was not mentioned, only 75% answered "yes".

Table 1:
Classification of the students according to ontological commitments and the groups' average response percentages to questions probing ontological commitments (see text).

Group	Subset 1	Subset 2	Subset 3	
A	17,3 %	100%	3,9%	n=13
B	64%	75%	39%	n=16
C	79,6%	91%	6,8%	n=22
D	91,2%	62%	95,6%	n =17
All	66,9%	81,65%	36%	n=68

Hypothetical reasoning

The second and third sets of questions probed intuitions on the properties and competences of an immaterial mind. Since the aim of the questions was to reveal the structure of conceptual organization of students' beliefs about material and non-material mental attributions, the structure of these questions was hypothetical: the students were asked to assume that *if* there existed an immaterial mind, independent of physical body, could it have such and such spatial or temporal attributes or such and such perceptual or cognitive abilities.

Looking at the responses in light of the classification discussed above, we could not establish any clear pattern between the four types of ontological commitments and the responses to hypothetical questions. Forcing the students to reason hypothetically therefore seems to tap into different similarities and differences than those that manifest in explicit ontological claims.

For example, each of the four groups contained subjects who associated spatial attributes with an immaterial mind (about 60% of the students, overall) and subjects who did not. For example, when asked if a an immaterial mind separate from the body nevertheless is located somewhere, 62% of the students answer "yes", while 56% thinks that if *reincarnation* of the soul were possible the soul would be located somewhere "in between the bodies", as it were.

When asked more closely about this transition, 46-59% - depending on the question - of the students said that the mind would occupy intermediate locations between the locations of the old and the new body (questions 53 & 59). This suggests that the students do indeed consider the location of a reincarnating soul as concrete physical or geographical location.

When the responses to hypothetical questions were fed into a SOM, thematically some thematically related items were found to form clusters on the map, others not. Questions relating to the spatial motion of immaterial mind (questions 57, 50, 60, 13, 26, 7, 28, 53, 59, 57, 55, 61, 16, 56, 63) are all located around the middle section of the map, but do not form a neat cluster (their distances from each other are large, as indicated by shading).

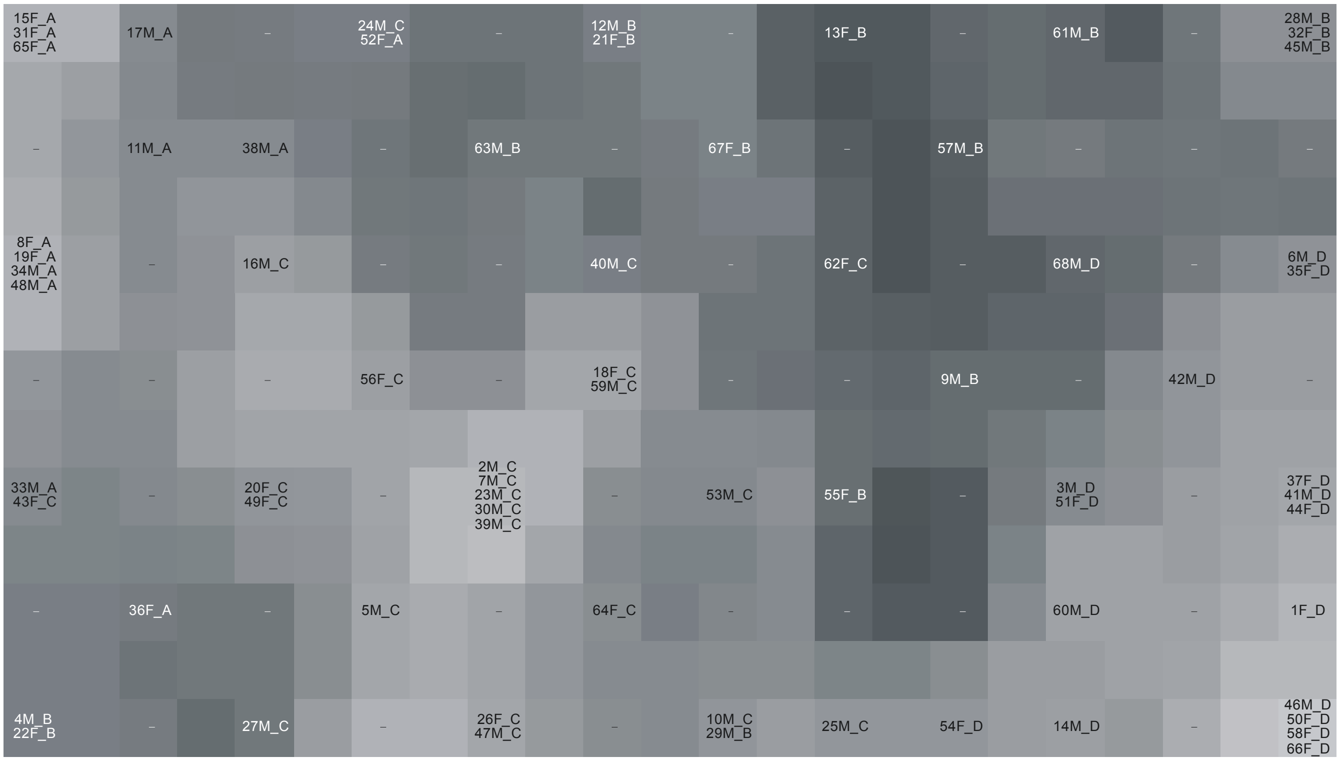

Figure 1: Self-organizing map of the students.
The map is based on the proximity of response patterns on questions probing ontological commitments. Darker square indicates longer distance in the input vector space. Students numbered 1-68 in no particular order. M = male, F = female. Labels A-D indicate membership in categories classified by a cluster analysis on the same data.

On the other hand, responses to the capacities an immaterial mind cluster much more tightly – but not into a single cluster.

Approximately 40% of students seemed to think that immaterial Cartesian minds, if such existed, could have abilities that are dependent on the sensory or perceptual processes (Table 2). For instance, 44% assumed a mind without a body could see colors (question 23), 40% thought it could see geometrical shapes (36), and according to 40% it could it hear sounds. Yet only 19% said the mind could feel heat (58), and only 18% said it could experience tastes. Looking at the distribution of the items related to perceptual and cognitive abilities of a hypothetical immaterial mind, we find the questions related to visual and auditory perception (39, 36, 23) in one tight cluster, questions related to feeling warmth and tastes (58 & 62) a little further, separated by questions asking whether alcohol intoxicates the body, the mind, or both (33, 30, 32) – with questions related to higher cognitive function (decision making 44, 51, thought and mental calculation, 41, 21). Apparently sensation – even in immaterial minds - is conceived differently from cognition. (More “bodily”, perhaps).

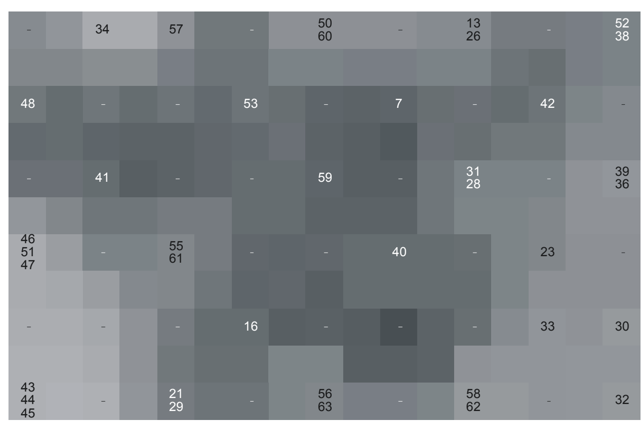

Figure 2.
SOM map of the hypothetical questions. Label refers to question item on questionnaire. Nearby items have similar response patterns across the sample.

Surprisingly, when higher cognitive (non-perceptual) abilities of an immaterial mind, such as an ability to make inferences, is considered, only about 60% of the respondents are willing to attribute such properties (see Table 2). According to some 40% of the respondents, Cartesian minds do not have characteristics Descartes considered essential to the soul, a difference of opinion on one of the main premises of a key argument in any introductory philosophy course.

The overall structure of the map suggests that the students do not share a clear and coherent set of beliefs on the spatiotemporal attributes of an immaterial mind, whereas in the case of sensory and cognitive capacities they are quite consistent. The question of internal coherence of this recurring set of belief remains an open question, however. The SOM map cannot address this question directly – however, it does show that if the students are incoherent, they are consistently incoherent in the same way.

Table 2: The abilities of an immaterial mind

Immaterial mind is able to	% of students
36. See geometrical shapes	40
23. See colors	44
39.Hear sounds	40
21.Make inferences & perform calculations	59
41.Count the number of ”objects of thought”	62
44.Make decisions	65
58. Feel heat	19
62. Taste tastes	18

Conclusion

We have presented a framework and an application for discipline-based research on philosophy learning. In our empirical design we focused on the initial state of the learning process – the novices' conceptions about philosophical topics students hold when they are first exposed to academic philosophy and the tradition of western philosophy. The aim of the study was not only to capture some features of philosophy novices' conceptual organization but also to give us a hint of the degree of their belief system's consistency coherence – whether students are all alike in their beliefs, and whether beliefs that should go together do go together. We believe this might offer a fertile and fruitful framework for investigating the transition process from the novice to the expert, as establishing conceptual coherence is precisely what learning philosophy is all about.

Acknowledgements

Eero Salmenkivi and especially Gualtiero Piccinini for commenting an earlier draft on this paper.

References

Bechtel, W. & Richardson, R. (1993). *Discovering Complexity, Decomposition and Localization as Strategies in Scientific Research*. New Jersey: Princeton University Press.

Carey, S. (1985). *Conceptual Change in Childhood*. Cambridge, MA: MIT Press.

Chi, M., T.H. (1992). Conceptual Change within and across Ontological Categories: Examples from Learning an Discovery in Science. In R. Giere (Ed.), *Cognitive Models of Science*. Minneapolis, MN: University of Minnesota Press.

Chi, M. & Slotta, J. (1993). The Ontological Coherence of Intuitive Physics. *Cognition & Instruction*. *10* (2 & 3), 249-260.

Chi, M. T H., Slotta, J. D., & de Leeuw, N. (1994). From Things to Processes: A theory of Conceptual Change for Learning Science Concepts. *Learning and Instruction, 4*, 27-43.

Craver, C. (2006). When Mechanistic Models Explain. *Synthese*, *153*, 355–376.

Cummins, R. (1983). *The nature of psychological explanation.* Cambridge, MA: Bradford/MIT Press.

DiSessa, A. A. (1988). Knowledge In Pieces. In G. Forman & P. Pufall (Eds.), *Constructivism in the Computer Age* (pp. 49-70). Hillsdale, NJ: Erlbaum.

DiSessa, A. A. (1993). Toward an Epistemology of Physics. *Cognition and Instruction*, *10*, (2 & 3), 105-225.

Limón, M., & Carretero, M. (1999). Conflicting Data and Conceptual Change in History Experts. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New Perspectives on Conceptual Change* (pp. 137-160). Amsterdam: Pergamon.

Murphy, G.L. & Medin, D.L. (1985). "The Role of Theories in Conceptual Coherence", *Psychological Review*, *92* (3), 289-316, 1985.

Kohonen,T. (2001): *Self-Organizing Maps*. 3rd edition, Springer, 2001.

McCloskey, M. (1983). Naive Theories of Motion. In D. Gentner & A. N. Stevens (Eds.), *Mental Models* (pp. 299-324). Hillsdale, NJ: Erlbaum.

Samarapungavan, A. & Wiers, R. W. (1997). Children´s Thoughts on the Origin of Species: A study of Explanatory Coherence. *Cognitive Science*, *21* (2), 147-177.

Slotta, J. D., Chi, M., T.H., & Joram, E. (1995). Assessing Students Misclassifications of Physics Concepts: An Ontological Basis for Conceptual Change. *Cognition and Instruction*, *13* (3), 373-400.

Strike, K.A. & Posner, G.J. (1982). ”Conceptual Change and Science Teaching”. *European Journal of Science Education*, *4* (3), pp. 231-240.

Thagard, P., & Verbeurgt, K. (1998). Coherence as Constraint Satisfaction. *Cognitive Science*, *22* (1), 1-24.

Thagard, P., Eliasmith, C., Rusnock, P., & Shelley, C. (2002). Knowledge and Coherence. In R. Elio (Ed.), *Common Sense, Reasoning and Rationality* (pp. 104-131). New York: Oxford University Press.

Vosniadou, S., & Brewer, W. F. (1992). Mental Models of the Earth: A Study of Conceptual Change in Childhood. Cognitive Psychology, 24, 535-585.Woodward, J. (2003): *Making Things Happen: a Theory of Causal Explanation*, Oxford: Oxford University Press.