Towards understanding conceptual formation in science education

André Machado Rodrigues
Ph.D., Student, University of São Paulo (Brazil), Officer, Secretariat of the Department of Education of São Paulo State

Cristiano Rodrigues DeMattos
Ph.D., University of São Paulo, Institute of Physics, University of São Paulo, Professor

In this paper we will discuss the concept formation in science education. It is well know that since 80's the most part of research in science education dealing with concept formation is related — directly or indirectly - with the conceptual change model. However, the science education research still lacks a consensual model to explain the concept formation considering the complex meaning negotiation dialogue within social interactions, both in school and daily life contexts. This theoretical discussion is important to point new directions to conceptual profile model research. The teaching-learning process in science education should not be limited to contents exposition. Toward an effective meaningful learning, teacher should also consider the conscious awareness as a target to meaning making. In this work Activity Theory is a relevant theoretical framework for understanding the teaching-learning of scientific concepts and to interpret the qualitative changes in this process. This approach opens the door to develop in two ways: embed the praxis in cognitive models on the one hand and insert communicative and semiotic processes in the Activity Theory on the other. We propose three categories that help us to understand the complex dynamics of teaching-learning process based on the dialectic interplay of the internalization and externalization.

Keywords: conceptual profile; activity theory; order of learning; science education; complexity.

Introduction

This paper brings the conceptual formation and use in the Science education up for theoretical discussion. In the last 30 years most part of research in Science education addressing conceptual learning focused on the conceptual change model [29]. In fact, the term — conceptual change — describes a complex theory that attempts to model the learning process answering how do learners make a transition from one «old» conception to a «successor» conception. However, usually this process was treated as the simple replacement of the preconceptions* by science conceptions.

Research on conceptual change has not been able to reveal the background of change, but several researchers have made important contribution to review and rethink the concept formation, in special scrutinizing the principles of conceptual change [29; 9; 10; 11; 6; 20; 36; see also 26; 27]. The main critics are summarized in four topics below:

(i) Affective aspects, values, feelings and motivations have been neglected in the conceptual change model.

(ii) A rational approach to science education has been excessively emphasized. From the educational point of view, one of the biggest problems of conceptual change model was the belief that learning is only effective when students abandoned his/her previous conceptions, replacing them with the «correct» — scientific ones — as usually taught in the science classroom.

(iii) Strike and Posner [36, p.14] claimed «that students' conceptual ecology should be view much more in terms of a dynamic system than as in the initial theory. There, the interaction of prior conceptions and the new conceptions was not sufficiently acknowledged». Actually, the conceptual formation must not be looked as a phase transition through static states.

(iv) The praxis and social level are completely forgotten in the conceptual change model. Considering the plurality and diversity of human activity that comes with its complex dialogical communicative dimension, the conceptual change research fails to understand the daily learning experiences and to relate formal school learning to other forms of learning.

Based on Vygotsky's and Bahktin's perspectives Mortimer [26] tries to further elaborate conceptual change model by emphasizing the relationship between speech and thought in concept formation. Mortimer points to the ecological diversity and plurality of concepts representation.

Our research questions rises from this ground. We are interested to understand what processes unite lan-

* There are differences amid «preconception», «misconception» and «alternative conception» and it is a important aspect of our discussion. However, here is not possible scrutinize this subject. For this see [16].

guage and activity; in fact we would like to understand how conceptual profile is united with the context (praxis).

Conceptual profile changes

The notion of conceptual profile [26; 27] enlarges the theoretical options to understand the teaching-learning process, mainly because considers the coexistence of «new knowledge» and the «old knowledge». Indeed, the coexistence of several views on the same concept allows us to understand better the case of students, which use scientific concepts in classrooms and preconceptions in daily life. In spite of underuse of some preconceptions at school stated in formal evaluations, a lot of evidences have been presented showing no concept substitutions. Instead coexistence in the same individual is manifested in different ways depending on the context he/she lives.

The conceptual profile model has its roots on Gaston Bachelard's [2] notion of epistemological profile. Bachelard illustrated his idea proposing a historical analysis of scientific concepts to show that their meaning could be found scattered in various philosophical schools. He classified the concept of mass into epistemological categories such as realistic, empiricist, rational classic and rational modern.

Bachelard's philosophical doctrine has been a useful philosophical tool, but as a model to explain the cognitive phenomenon it is very limited [12]. Transposing the epistemological model to a cognitive model, Mortimer [26; 27], preserved the same structure of the epistemological profile. According to Mortimer: «the conceptual profile should have some similarities with the epistemological profile, such as hierarchies among the different zones, by which each successive zone is characterized by having categories with more explanatory power than its antecedents» [26, p. 272—273].

Mortimer [26] built a conceptual profile of mass based on the same categories Bachelard has used. Based on empirical evidences Mortimer proposed a histogram of epistemological categories versus subject's frequency of use. The figure 1 shows Mortimer's representation of the conceptual profile of mass.

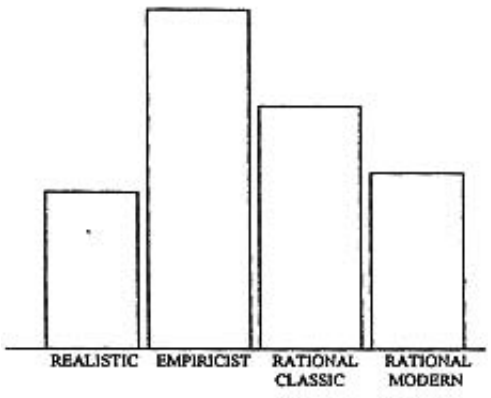

Fig 1. Mortimer's conceptual profile on «mass» concept

Henceforward, a lot of works focusing on assessment; theoretical development and critical reviews are produced in the science education [35; 1; 8; 12]. The methodology consists of the choice of a concept taught in the regular school and passing to the student a questionnaire presenting some situations. Part of the questions assesses opinions and the other one to solve a problem. Educational intervention data analyze the efficacy of the intervention using pre and post setting.

As Mortimer already indicated this framework allows exploring the dynamics aspect of learning as a change or evolution on the conceptual profile dealing with one of the most important methodological challenge in education, the assessment. According to Mortimer [26, p. 284] «an important question to be addressed in this research is how to determine the profile of each individual before and after teaching and to what extent He or She achieves a consciousness of this profile at the end of the teaching process». In this framework the dynamics aspect of learning could be understood as a change or evolution in the conceptual profile. Mortimer already indicated to the methodological challenge of Science education assessment.

We think that the conceptual profile model can be improved. Recently we have criticized «theoretical» and «methodological» uses of the model. We believe that the model includes important principles considering the plurality and diversity of representations of the world. However, we understand that this framework could be more consistent if the *praxis* were included.

Mortimer [27] points to the existence of a relationship between conceptual profile and context, assuming that the conceptual profile is «context-dependent, since it is strongly influenced by different experiences of each individual, and content dependent, since, for each concept has a different profile» [27, p. 80]. On the other hand, given context important influence, we must take into account the relationship between conceptual profile and context when conducting research on the conceptual profiles. Our studies [32; 33] pointed out that ignoring context as a relevant factor in research can lead to misinterpretation of data.

The close relationship between learning, utterances and the conceptual profiles zones' contexts of use, demands integration of the notion of context as a central element in the theoretical and methodological framework of the conceptual profile model. It is helpful to understand what kind of criteria — contextual markers — students use when are dialoging in different context, *p. e.*, daily or scientific context. In other words, how do we decide to use one class of knowledge?

El-Hani and Mortimer [12] improved the notion of conceptual profile using questions embedded in the philosophy of science. They situate the conceptual profile notion in a middle position, escaping from the clash between universalism and multiculturalism. However, their arguments remain tied only to an epistemological ground. Then, every goal for science teaching is connected only with epistemology — mainly science — and the internal questions related to it.

Including context

In fact, our interest is the text produced in human activity, i. e., human discursive production in their social relations. Particularly we are interested in the teaching and learning of concepts emerged from the social situation we call classroom. This is a complex process of meaning negotiation — a context negotiation.

The notion of context has been studied by many authors [28; 13; 7; 14; 15; 17]. In despite of some consensus among researchers about the importance of the notion of context, its polysemy forbids an unambiguous definition [7; 15].

In a brief review about the concept of «context» [31; 23; 37] we could recognized its complexity and multilayeredness. Nevertheless, our intention is not to exhaust this subject, but to show how heterogeneous and diverse it can be. The diversity of meaning is not a theoretical or methodological problem we overcome by an exhaustive search for a hermetic or complete definition of what «context» is. On the contrary, this diversity should be used as an intrinsic property of the context notion.

Recently, Gilbert [15] showed how the context is being addressed in some theoretical perspectives in different fields of science education research. He looked for what treatment context has from curricular issues to activity theory. From a contextual approach, Gilbert proposed extracting criteria to assess and to build the science curriculum, and particularly, the chemistry curriculum. On other hand, Finkelstein [14] discusses the model; Cole [7] proposed adapting it to teaching and learning situations in physics classrooms. Finkelstein [14, p. 119] explores the idea of «frames of context», suggesting that there are interactions between each frame considering how those layers interactions affect teaching electromagnetism.

In despite of the way context is conceived, one of the most common ideas is that actions and discourse produced in social interaction, are characterized as dependent variables, while the surroundings are an independent variable. This idea does not allow conceiving productions and discursive activities as part of an «ecology of ideas which together constitute the small subsystem which I call "context"» [4, p. 338].

We are aligned with Bateson working the context as a «complex system», i. e., a system composed by a great number of elements arranged in several different hierarchical levels of interaction. Thus distinguish amid a lot of contexts implies reading its several hierarchical levels which includes the subject and his relative position in the world — discursive position.

A subject could recognize contexts during a dialogical interaction instance is he/she discerns the «context marker», as proposed by Bateson:

But, certainly in human life and probably in that of many organisms, there occur signals whose major function is to classify contexts. It is not unreasonable to suppose that when the harness is placed upon the dog, who has had prolonged training in the psychological laboratory, he knows from this that he is now embarking upon a series of context of a certain sort. Such a source of information we shall call a «context marker», and note immediately that, at least at the human level, there are also «markers of contexts of contexts» [4, p. 289—290].

Bateson also brings the notion of «contexts of contexts», corroborating the complex perspective we introduced and driving us to understand various phenomena related to communication and learning. Bateson points out how context markers relate to the context allowing «meanings making» in different hierarchical levels.

For example: an audience is watching Hamlet on the stage, and hears the hero discuss suicide in the context of his relationship with his dead father, Ophelia, and the rest. The audience members do not immediately telephone for the police because they have received information about the context of Hamlet's context. They know that it is a «play» and have received this information from many «markers of context of context» — the playbills, the seating arrangement, the curtain, etc., etc. The «King», on the other hand, when he lets his conscience be pricked by the play within the play, is ignoring many «markers of context of context». [4, p. 290].

The construction of dialogic interaction utterances is ruled by context recognition. In his work, Bernstein [5] distinguishes children's explanatory forms of worker class and middle class children, stressing that differences between children is not a difference of ability or cognitive, but a difference of recognition and realization rules they use to read the context, select your interactive practice and create their texts.

Recognize context marks allows the emergence of certain utterances in detriment of others. Context recognition implies the recognition of the relative positions those context marks occupy in the discursive-interactive space.

A shared context is constituted during meaning negotiation, based on the construction of teacher's and students' intersubjectivity [34]. To share some context marks allows establishing the opening of a meanings negotiation, a game that is kept on until the mutual perception of a communication success. The perspective of the context as complex object built in an interactional dialogic situation «allows to apprehend the text and the context, the being and the environment, the place and the global together, the multidimensional, in short, the compound, that is, the conditions of the human behavior». [25, p. 100]. Then, the context is dialectical overcoming antinomies [3].

To express an object as a complex system directly drives us to the methodological problem of how to observe it. The limitation of representation instruments leads us to choose cuttings of the object. We intend to consider on specific cuttings of this complex object that allow us to reveal aspects of the complexity of the system in the case of sciences teaching.

According to Nardi, there is a similarity between the notions context and activity.

Activity theory, then, proposes a very specific notion of context: the activity itself is the context. What takes place in an activity system composed of object, actions,

and operation, is the context. Context is constituted through the enactment of an activity involving people and artifacts. Context is not an outer container or shell inside of which people behave in certain ways. People consciously and deliberately generate contexts (activities) in part through their own objects; hence context is not just «out there» [28, p. 38].

Towards teaching-learning dynamics

Considering Vygostsky's concept development process we step away from associationism and naive realism [38; 39], and from generalization understood as finished and static state of the concepts formation.

We previously associated teaching-learning as dynamic communication process, to deal with this complex process we proposed the «orders of learning» as a conceptual profile?s dynamics markers [21]. Those learning orders can be also considered as markers of the dynamic processes of internalization and conscious awareness.

Internalization process

Internalization is one of the most important concepts of on socio-cultural-historic theories. It has a central role to understand learning process and the development of consciousness.

Zinchenko's radical view, argues «that the word accompanies a person from the moment of birth» [41, p. 5]. On the other hand, using a classical definition, Wertsch situate internalization «as a process whereby certain aspects of patterns of activity that had been performed on an external plane come to be executed on an internal plane» [40, pp. 61-62]. Both perspectives point to wide view of internalization process, which should include all genetic domains. At last, internalization idea could be expressed as a process where the complexity of external world helps to build the complexity of the essentially internal psychic world. Based on Activity theory we could say that the complex external world is composed by an ecology of human activities emerged in its all diversity as a complex coordination of operations and actions reflected and refracted during learning process. From this point of view we internalize activities that coordinated to others became actions that coordinated to others became operations, a continuously process representing the generalization continuous process. This complex process of synthesis allows the emergence of new activities.

To transform the child's action in operation we must give him a new goal in which the action becomes the means to carry out another action. In other words, what was the goal of the first action must become one of the conditions of required action by the new goal. [19, p. 183—184].

Leontiev [19] exemplify this complex process with arithmetic's learning process. Arithmetic can be an action or an operation *a priori*. Nevertheless for the novice it presents itself as an action with conscious goals, little by little in their learning process he internalizes it and its conscious action becomes to solve a broader problem and no more the arithmetic construction. In this example, especially the new problem presented may be the learning of algebra. With the exchange of actions in operations, the novice will be able to solve even more complex problems.

We worked on this topic making a theoretical reconciliation between activity theory and complex systems features through the notion of internalization [21]. According to this work, the word «force», hides a number of processes and operations that is summarized in the word. To operate with the idea of force is not necessary that all operations that compose consciousness must be present at all times.

This process makes possible to speak about force, mass, energy without necessarily having to expose all conceptual net supporting its complete understanding — underlying operations, this is where we identify the lexical density. The fact that these concepts are operationalized does not mean they vanish from subjects' conscience, since during externalization process operationalized concepts are always coming back to mind emerging as actions. This process — to internalize the external actions — influences subject's cognitive ability as well as change its own conceptual world.

To begin with, consciousness exists only in the form of a mental image revealing the surrounding world to the subject. Activity, on the other hand, still remains practical, external. At a later stage activity also becomes an object of consciousness; man becomes aware of the actions of other men and, through them, of his own actions. They are now communicable by gestures or oral speech. This is the precondition for the generation of internal actions and operations that take place in the mind, on the «plane of consciousness». Image-consciousness becomes also activity-consciousness. It is in this fullness that consciousness begins to seem emancipated from external, practical sensuous activity and, what is more, appears to control it [18, p. 100].

Another important process is the apparently inverse of internalization — the externalization process, when the operation comes back to consciousness.

Conscious awareness

Another important point is the inseparability of teaching-learning internalization processes consisting of the mechanism of conscious awareness. Vygotsky [38; 39] extensively discussed about conscious awareness, criticizing the idea that it occurs naturally, spontaneously or purely by biological maturation, and pointing to the importance of social nature of this mechanism. Hence Vygotsky [38, 39] sees school's primary function and formal education contributes to the conscious awareness, a child at school begins his/her education to literacy of what he/she knows from his/her previous experience.

In the spheres of attention and memory, then, the school child manifests a capacity for conscious awareness and voluntary behavior. Indeed, the emergence of this capacity is the central feature of mental development during the school age [39, p. 187].

In this sense, school life brings besides internalization of new discursive genres, a conscious awareness of earlier

internalized quotidian discourse. Then objects are internalized as new instruments allowing to see new objects opening new paths to new internalization processes.

The school's merit to develop superior psychological functions, consists to make possible arbitrary processes — operations — that are automatically daily realized, come to the level of action brought to consciousness trough the teaching-learning process [18, 19]. This process of bringing to the sphere of consciousness the unconscious is carried out by the educational activity itself, complementing the internalization process.

Children start to learn during their life a lot of concepts, that are internalized and at some moment operationalized. For instance, a child identifies her mother and learns to use the concept in the proper context. However, when the child is asked «what is the mother?», or when asked to define the concept, the child has difficulty and cannot do it immediately.

The same occurs with other concepts, as time, for instance. Most of people can use and operate with a time concept in their daily life. Although when someone asks them «what is time?», it requires a kind of cognitive effort to bring this specific concept to our consciousness. We could develop our argument discussing other examples of science education. Generally students solve standard problems using correctly Physics formulae, which were internalized to the operational level. Nonetheless solving exercises and problems, even in classical or modern physics, when students are asked about the concept definition, its structure of relations with other concepts, they have a lot of difficulty.

From this perspective teaching-learning process is a multilayer phenomenon mediating and organizing contexts and activities to different qualities of conscious awareness. From our point of view conscience is the emergence of coordination of conceptual profiles zones resonating with the subject's living contexts. This resonance evolves during context markers negotiations considering subjects consciousness during dialogical interaction.

Orders of learning

Bateson proposed such acquisitions might occur in two forms, the «zero learning» and the «Learning I» [4, p. 284]. Based on game theory, Bateson understands that novices learn just through random exploration, building on their decisions. Then, «zero learning» could be characterized as a stimulus and response scheme where each stimulus runs independently. Each piece of information is always new and the organism is unable to correct errors based on it. Bateson called «Learning I» [4, p. 287] to go further in its appropriation of Pavlov reflexology. He based «Learning I» on the behaviors created by conditioning and reinforcement assuming that subjects have the ability to distinguish contexts linking them to specific stimuli even if the contexts are hierarchically organized. From this point of view, subjects consider the history of stimuli and responses to decision making. Then, subjects could correct errors based on historical information.

Our proposal is far from behaviorist position, and Bateson comes over here to support the introduction of man-world interaction complexity. From this point of view, the orders of learning are proposed to help us understand subjects learning of new discursive positions in context, *i. e.*, we want to understand how we learn being in the world.

We propose the learning orders as «learning markers» instead to introduce a learning dynamics that could be partially inferred from those orders as we can see in the next section.

First order of learning

To deal with novices learning we introduce the first order of learning to refer the subject's addition of new zones of a conceptual profile. In general, intervention strategies and research aligned with conceptual change seek out to modify or assess the changes occurred.

Using Activity Theory background this order of learning marks the stage of non conscious operations, in other words, a kind of instrumentalization. In this case operations are shaped by immediate material conditions of production. Then the appropriation of concepts indicates the appropriation of mental operations, which appear primarily as external actions, and then, are transformed in inner intellectual operations [19].

We refer here to the most elementary internalization process, in which actions are appropriated and become operations. In general operations are non conscious at all.

First order of learning can be thought in terms of a consciousness category representing subject's initial conceptual profile zone. The correspondence between the conceptual profile zone and its context of use indicates the validity of subject's utterances. This conceptual profile zone could resonate just with one specific context, for instance, a quantum mechanical class, or with any context indicating subject non discernment of context markers. In this sense the conceptual profile zone could be seen as an amalgam of zones. Consequently, school's context shapes zones that could resonate just inside this context. Similarly, use of daily concepts will be delimited to daily contexts without connections to school context.

Second order of learning

Considering the second order of learning conceptual profile changes not only due by new internalizations, but also a qualitative change of conceptual profile zones. Two different changes can happen: the amalgamated conceptual profile zone is split in different zones or a new zone is added to the previous conceptual profile. In both situations subjects make correct utterances in each context relating correctly contextual markers and the use of word meaning. For instance, the subject could use both correctly the Newtonian zone of the conceptual profile of mass during a classical mechanics class and the relativistic zone of the conceptual profile of mass during a general relativity class. Nevertheless the subject's zones of the conceptual profile of mass resonates adequately with the specific contexts, nevertheless he/she does not have consciousness of that correct use. He/she uses of these zones without intentionality — clear purpose or arbitrarity — is met even less in a new context. The subject simply uses

the zone of the conceptual profile being aware of making a correct utterance, although not aware of all meanings word have. Then, the recognition of different contexts is non intentional — still mechanical — and operative.

However, during this stage appears the possibility of «coordination of actions» [22] emerges at the upper level of consciousness. The potentiality of this level appears also as possibility of explicit meaning negotiation.

Third order of learning

The third order of learning can be defined by the subject's conscious awareness of the relationship between conceptual profile zones and the possible contexts of use. At this level subjects understand how contexts markers are distributed the situation he/she is inserted.

When subject is conscious of the relationship between conceptual profile zones and the appropriate contexts of use, he/she is able to articulate and interpret others' utterances properly. He/she is aware that a physical definition of mass does not always fit in all contexts. He/she realizes uses and limits of the conceptual profile zones in different contexts and, at same time, contexts' boundaries. Conscious subject can figure out his/her different «zones» giving different meaning to the concepts, recontextualizing contexts and choosing appropriates zones to communicate successfully with others.

Considering a meaningful learning perspective, Moreira [24, p. 168] warns that «[...] meaningful learning is not synonymous of 'correct' learning. A student can learn in a meaningful but a 'wrong' way, *i. e.*, he can attribute meaning to concepts that, for him, entails meaningful learning, nevertheless for the teacher are wrong because they are not shared by the users community». It happens because at the time of explanation, teacher and student are inserted in different contexts. In the third order of learning this problem disappears, and students become aware not only of parts of the profile, but also the possible contexts in which it is inserted.

Subjects at the third order of learning have a meta-consciousness, which allows him/her to observe intercontextuality — a situation as multi-contextual — , identifying different context markers. Maturana and Varela [22] proposed the coordination of coordination of actions, as a hierarchical upper level of structural representation. Thereby, they established a hierarchical organization for both context and is internal representation.

As a direct consequence of the third order of learning, subject becomes capable to intentionally select analogies, metaphors and ironies, crossing context's boundaries and finding new meaning to communicate an idea.

Conclusion

This theoretical discussion proposes new directions to conceptual profile research. The teaching-learning process in science education should not be limited to contents exposition. To achieve an effective meaningful learning, teacher should also consider the conscious awareness as a target of meaning making.

This work evidences the relevance of Activity Theory as a theoretical framework to understand learning of scientific concepts and interpret the qualitative changes in subject's learning. This approach points out theory to be developed in two ways: (i) embed the praxis in cognitive models on the one hand and (ii) integrating communicative and semiotic processes into Activity Theory on the other.

Finally, we cannot think on concept learning solely, but we have to think about learning of concepts in contexts, inserted in specific social practice.

References

1. *Amaral E. M. R., Mortimer E. F.* Uma metodologia para estudar a dinâmica entre as zonas do perfil conceitual no discurso da sala de aula / In: Santos F., Greca I (org.). A pesquisa em Ensino de Ciências no Brasil. Ijui, 2006.

2. *Bachelard G.* The Philosophy of No. A philosophy of the new scientific mind. N. Y., 1968.

3. *Bakhtin M.* Marxismo e filosofia da linguagem: problemas fundamentais do método sociológico da linguagem. São Paulo, 2006.

4. *Bateson G.* Steps to an ecology of mind. Chicago, 2000.

5. *Bernstein B.* A estrutura do discurso pedagógico: Classe, código e controle. Petrópolis, 1996.

6. *Carey S.* Sources of conceptual change / In: E. K. Scholnick, K. Nelson, & P. Miller (Eds.) Conceptual development: Piaget's legacy. Mahwah, N. J., 1999.

7. *Cole M.* Cultural psychology. A once and future discipline. Cambridge, 1996.

8. *Coutinho F. A., Mortimer E. F., El-Hani C. N.* Construcão de um perfil para o conceito biológico de vida // Investigacoes em Ensino de Ciencias. 2007. Vol. 12, № 1.

9. *diSessa A. A.* A history of conceptual change research: Threads and fault lines / In: K. Sawyer (Ed.) Cambridge handbook of the learning sciences. Cambridge, 2006.

10. *Duit R., Treagust D. F.* Conceptual change: a powerful framework for improving science teaching and learning // International Journal of Science Education. 2003. Vol. 25, № 6.

11. *Duit R., Treagust D.* Learning in science - From behaviourism towards social constructivism and beyond / In: B. Fraser & K. Tobin (Eds.) International handbook of science education. Dordrecht, The Netherlands, 1998.

12. *El-Hani C. N., Mortimer E. F.* Multicultural education, pragmatism, and the goals of science teaching // Cultural Studies of Science Education. 2007. Vol. 2.

13. *Engeström Y., Miettinen R., Punamäki R.-L.* Perspectives on activity theory. Cambridge, 1999.

14. *Finkelstein N.* Learning Physics in Context: A study of student learning about electricity and magnetism // International Journal of Science Education. 2005. Vol. 27. № 10.

15. *Gilbert J. K.* On the Nature of «Context» in Chemical Education // International Journal of Science Education. 2006. Vol. 28. № 9.

16. *Gilbert J. K., Watts D. M.* Concepts, Misconceptions and Alternative Conceptions: Changing Perspectives in Science Education // Studies in Science Education. 1983. Vol. 10. № 1.

17. *Givry D., Tiberghien A.* Studying the evolution of student's ideas in a physics classroom // In: V ESERA. Barcelona, 2005. Vol. 1.

18. *Leont'ev A. N.* Activity, consciousness, and personality. Englewood Cliffs, N. J., 1978.

19. *Leontiev A. N.* O Desenvolvimento do Psiquismo. Lisbon, 1978.
20. *Linder C. J.* A challenge to conceptual change // Science Education. 1993. Vol. 77.
21. *Mattos C. R., Rodrigues A. M.* Theoretical Consideration about conceptual profile dynamic // VI ESERA. Malmö. 2007. Vol. 1.
22. *Maturana H., Varela F.* A arvore do conhecimento. Saõ Paulo, 2007.
23. *Mayhew S.* A dictionary of geography. Oxford, 1997.
24. *Moreira M. A.* Aprendizagem significativa. Brasilia, 1999.
25. *Morin E.* The seven complex lesson in education for the future. Paris, 1999.
26. *Mortimer E. F.* Conceptual Change or Conceptual Profile Change? // Science & Education. 1995. Vol. 4.
27. *Mortimer E. F.* Linguagem e formacão de conceitos no ensino de ciencias. Belo Horizonte, 2000.
28. *Nardi B. A.* Studying Context: A Comparison of Activity Theory, Situated Action Models, and Distributed Cognition / In: B. A. Nardi (ed.) Context and Consciousness: Activity Theory and Human-Computer Interaction. Cambridge, 1996.
29. *Özdemir G., Clark B.* An Overview of Conceptual Change Theories. Eurasia Journal of Mathematics // Science & Technology Education. 2007. Vol. 3. № 4.
30. *Posner G. J., Strike K. A., Hewson P. W., Gertzog W. A.* Accommodation of a scientific conception: Toward a theory of conceptual change // Science Education. vol. 66, № 2, 1982.
31. *Richards J. C., Platt J., Platt H.* Longman Dictionay of language teaching and applied linguistics. Essex, 1992.
32. *Rodrigues A. M., Mattos C. R.* The complex dynamic of the learning activity // In: XIV IOSTE. Bled. 2010. Vol. 1.
33. *Rodrigues A. M.* Redimensionando a nocão de aprendizagem nas relacoes entre perfil conceitual e contexto: uma abordagem sócio-cultural-histórica. São Paulo, 2009.
34. *Rommetveit R.* On the Architecture of Intersubjectivity / In: Rommetveit R. and Blakar R. M. (Eds.) Studies of Language Thought and Verbal Communication. London, 1979.
35. *Silva F. A. R.* O perfil conceitual de vida: ampliando as ferramentas metodologicas para sua investigacão. Belo Horizonte, 2006.
36. *Strike K. A., Posner G. J.* A revisionist theory of conceptual change / In: R. A. Duschl & R. J. Hamilton (Eds.) Philosophy of science, cognitive psychology, and educational theory and practice. N. Y., 1992.
37. *van Dijk T. A.* Discourse, context and cognition // Discourse Studies. 2006. Vol. 8. № 1.
38. *Vigotski L. S.* A Construcão do Pensamento e da Linguagem. São Paulo, 2001.
39. *Vygotsky L. S.* The collected works // In: Problems of general psychology. Vol. 1. N. Y., 1987.
40. *Wertsch J. V.* Vygotsky and the social formation of mind. Cambridge, 1985.
41. *Zinchenko V.* The earliest stages of the cultural development of the child // ISCAR. San Diego, 2008. Vol. 1.

К пониманию формирования понятий при обучении естественным наукам

Андрэ Мачадо Родригес
аспирант Университета г. Сан Пауло (Бразилия), сотрудник секретариата департамента образования штата Сан Пауло

Кристиано Родригес ДеМаттос
кандидат физико-математических наук, профессор Института физики Университета Сан Пауло

В работе обсуждается формирование понятий в процессе обучения естественным наукам. Хорошо известно, что с 80-х годов большая часть исследований в области обучения естественным наукам, посвященным формированию понятий, связана — прямо или косвенно — с моделью понятийных изменений. Однако в исследованиях в области обучения естественным наукам до сих пор нет согласованной модели, которая бы объясняла формирование понятий, учитывая сложный диалог о значении, в рамках социальных взаимодействий как в контексте школы, так и в повседневной жизни. Данное теоретическое обсуждение важно для проектирования новых направлений в исследованиях модели понятийного профиля. Процесс преподавание-обучение в области обучения естественным наукам не должен быть ограничен разъяснением содержания. Учитель для обеспечения эффективного и осмысленного обучения должен также принимать во внимание осознанную осведомленность в качестве цели при создании смыслов. В данном контексте теория деятельности является подходящей теоретической основой для понимания процесса преподавание-обучение научных понятий и для интерпретации качественных изменений в этом процессе. Данный подход позволяет развиваться в двух направлениях: включить праксис (действия) в когнитивные модели, с одной стороны, и добавить коммуникативные и семиотические процессы в теорию деятельности с другой. Предложены три категории, способствующие пониманию сложной динамики процесса преподавание-обучение, основанные на диалектическом взаимодействии интернализации и экстернализации.

Ключевые слова: концептуальный профиль, теория деятельности, порядок обучения, обучения естественным наукам, комплексность.