CULTURAL AND HISTORICAL PERSPECTIVES ON SCIENCE EDUCATION: RESEARCH DIALOGS

Activity Theory in Formal and Informal Science Education

Katerina Plakitsi (Ed.)

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ACTIVITY THEORY IN FORMAL AND INFORMAL SCIENCE EDUCATION

CULTURAL AND HISTORICAL PERSPECTIVES ON SCIENCE EDUCATION: RESEARCH DIALOGS

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Research dialogs consists of books written for undergraduate and graduate students of science education, teachers, parents, policy makers, and the public at large. Research dialogs bridge theory, research, and the practice of science education. Books in the series focus on what we know about key topics in science education – including, teaching, connecting the learning of science to the culture of students, emotions and the learning of science, labs, field trips, involving parents, science and everyday life, scientific literacy, including the latest technologies to facilitate science learning, expanding the roles of students, after school programs, museums and science, doing dissections, etc.

Activity Theory in Formal and Informal Science Education

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TABLE OF CONTENTS

KATERINA PLAKITSI

1. ACTIVITY THEORY IN FORMAL AND INFORMAL SCIENCE EDUCATION

The ATFISE Project

INTRODUCTION

This book aims to contribute to an emergent agenda for cultural historical activity theory (CHAT) and science education in Europe. It especially focuses on the application of activity theory in formal and informal science education. This focus leads to rethinking scientific literacy (Roth & Lee, 2004), as well as to rethinking the role of information and communication technologies (van Eijck & Roth, 2007; Kaptelinin & Nardi, 2006). Recently, many European science curricula have been reformed, but by interpreting evaluation reports of the Programme for International Students Assessment (PISA, 2006, 2009)[1] we see that we still have to do a lot in order to achieve the aim of "real" scientific literacy.

CHAT is considered a subcategory of sociocultural theory, and this issue will be analytically described in Chapter 2. A science education enriched and interpreted by CHAT could be situated in the current sociocultural context. During recent decades many scholars in the United States, Canada, Australia, and Europe have developed theoretical documentation and research methods on CHAT. Some important academic journals in science education research, such as *Science Education, Research in Science Education,* and *Journal of Research in Science Teaching,* increasingly include cultural studies of science education. The journal *Cultural Studies of Science Education* is totally oriented to this emerging research field. In this journal many senior and new authors publish work devoted to the cultural interpretation of science education practices and activities.

Among European science education policies, however, this emergent agenda remains isolated, although "learning communities," "potentials for learning," and "quality in science education research" are major topics in recent European journals, conferences, and books.[2] European science education scholars are underrepresented in this research area. For example, during the European Science Education Research Association (ESERA) conferences, few symposia were dedicated to cultural studies of science education (CSSE). Moreover, the average number of sociocultural articles in the leading European science education journal, *International Journal of Science Education* is low. We need more concerted work on major sociocultural and cultural-historical issues. Until now the discourse has been limited primarily to language, globalization, and immigration. European citizens differ from those in third-world countries, while science approaches in European countries may differ

K. Plakitsi (ed.), Activity Theory in Formal and Informal Science Education, 1–15.

significantly from those in Canada, the United States, and Australia. Furthermore, many types of science, for example science of western civilizations, personal science and indigenous science, can occur simultaneously in a learning community.

The traditional dualistic framework does not help us understand current complex social interactions. More than ever before, there is a need for an approach that can dialectically link the individual with social structure. From its very beginnings, the Cultural-Historical Theory of Activity (CHAT) considered this task as a priority (Engeström, 1999). Activity theory has its origins in classic German philosophy (from Kant to Hegel), in the writings of Marx and Engels, and in the Soviet Russian cultural-historical psychology of Vygotsky, Leont'ev, and Luria. Today activity theory is becoming truly international and multidisciplinary. This process entails the discovery of new and old related approaches, discussion partners, and allies, ranging from American pragmatism and Wittgenstein to ethnomethodology and theories of self-organizing systems (Engeström, 1999, p. 20). Activity theory is a framework or descriptive tool (Nardi, 1996) that provides "a unified account of Vygotsky's proposals on the nature and development of human behaviour" (Lantolf, 2006, p. 8).

Two of CHAT's most important contributions concern mediation and changes in human behavior. The first idea is that mediation with tools is not merely an idea. It is an idea that breaks down the Cartesian walls that isolate the individual mind from culture and society. The tools are both mental and physical. Examples of mental tools are the ability to measure, language (langue), and even some historical scientific experiments which changed our world. Examples of physical tools are magnifying glasses, simple balances, a textbook, operations on a PC, a social robot, or language (parole). Tools take part in the transformation of the object into an outcome, which can be desired or unexpected. They can enable or constrain activity.

The second important idea is that humans can control their own behavior—not "from the inside," based on biological urges, but "from the outside," using and creating artifacts.

Describing in brief the components of an activity represented in Figure 1, we mention subject, object, tools, rules, community, division of labor, and outcomes.

The subject of an activity system is the individual or group whose viewpoint is adopted.

An object "refers to the 'raw material' or 'problem space' at which the activity is directed and which is molded or transformed into outcomes with the help of physical and symbolic, external and internal *tools*" (Engeström, 1993, p. 67, italics in the original). It precedes and motivates activity.

The interaction between the subject and the object is mediated by the *tools*, but it is simultaneously influenced by the rules, the community, and the division of labor.

The rules are explicit and implicit norms that regulate actions and interactions within the system (Engeström, 1993; Kuutti, 1996).

Community refers to participants in an activity system who share the same object.

The division of labor involves the division of tasks and roles among members of the community and the divisions of power and status.

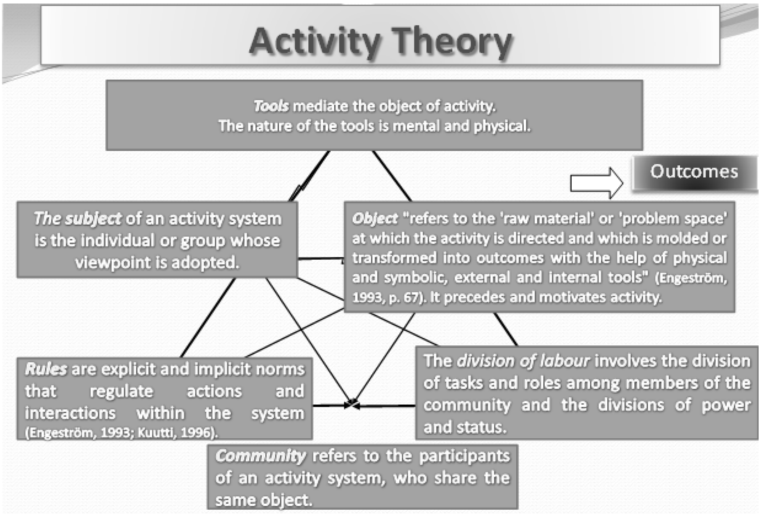

Figure 1. Components of the activity system (Engeström, 1987).

Apart from the basic triangle of CHAT, many prominent socioculturalists have supported some major trends of the theory. We focus on the concept of participation (Roth & Lee, 2004). Science education as participation in the community can work as a syllabus for teachers/researchers in science education who are rethinking the scope of scientific literacy. The core tendency is to construct theoretical assertions from an example or a case study. Some may consider this approach to be methodologically problematic, but we oppose this view, because each specific situation can contribute to a bottom-up approach to rethinking science education in a sociocultural context. We also oppose the formation of the theoretical assertions following a top-down approach, for example, from general pedagogical principles to everyday practices. We believe that it cannot help practitioners apply CHAT in their everyday settings because of the gap between general principles and practice.

Furthermore, a very recent study describes children's development as participation in everyday practices across different institutions (Hedegaard & Fleer, 2010). Institutions can either be the home or the school that most children share. Apart from the differences, there is a common core framed by societal conditions. Two theories can be combined in this approach: (1) Vygotsky's theory (1998) of the social situation of development and (2) Hedegaard's (2009) theory of development as the child participates within and across several institutions. The processes within and across those institutions have to be considered dialectically. This leads to the necessity for a new epistemology,[3] which is multiculturalism. Multiculturalism fits Hedegaard's psychological theory, as it legitimizes the different institutions as frameworks of knowledge acquisition and behavioral change. In this dialectical process "in which a transition from one stage to another is accomplished not as an evolving process but as a revolutionary process" (Vygotsky, 1998, p. 193), Fleer and Hedegaard (2010) invite teachers to project-based learning beyond children's current capacities in ways which are connected with their growing sense of themselves within their communities or institutions (p. 150). Consequently, teachers need to do a context analysis and study the evolution of children's conceptualization of scientific issues. Teachers must locate the points of crisis, always taking into account the social situation of child development. We can assert that Vygotskian revolutionary theory corresponds to the Kuhnian revolutionary epistemology about science. We also have to study not only changes in the child and changes in the environment, but changes in the child's relationship with the environment (Kravtsova, 2006). Danish and Australian case studies in Fleer and Hedegaard's (2010) work illustrate the conflicts within the child – inner conflicts – which have a major influence on the child's behavior, on relationships with the teacher and other children, and on his or her knowledge acquisition process. There is a great deal of literature on this topic; we only mention the argument on development to the extent to which "development can be understood only in light of the cultural practices and circumstances of their communities – which also change" (Rogoff, 2003, pp. 3-4). According to Rogoff (2003), development can be viewed as a transformation of participation in cultural activities, through which individuals change, thereby changing the communities within which they live.

In Hedegaard's work, the concept of institutional practice is the connecting link between Rogoff and Vygotsky's points of view and a step forward to the relevant discussion. According to the latest discussion, we are challenged to see that development takes place when a child participates in practices through different institutions. Figure 2 illustrates Hedegaard's model of development, which is strongly related to the Vygotskian tradition of societal development. We think that this visualization provided by Marianne Hedegaard can help teachers and researchers better understand the relationships within societal, institutional and individual participation in childen's development. Moreover, we can expand this approach, grounding our projects described in Chapters 7 and 8 on the dialectical participation of formal and informal science education.

Combining Vygotsky (1998) and Hedegaard (2009), we should not fear crisis but rather should see crisis as a dynamic context for development. We think that this conception of crisis can lead us to the opposite of cognitive conflict in the Piagetian tradition. Cognitive conflict, however, is considered an inner procedure, and its solution can be mediated by the teacher. It is therefore oriented more to the inner child and his or her cognitive domain and does not take into account the total pedagogical and societal environment. Researchers on social constructivism tried to take into account the societal factor in child development, but they remained anchored to the individuality and did not address the gap between theory and praxis.

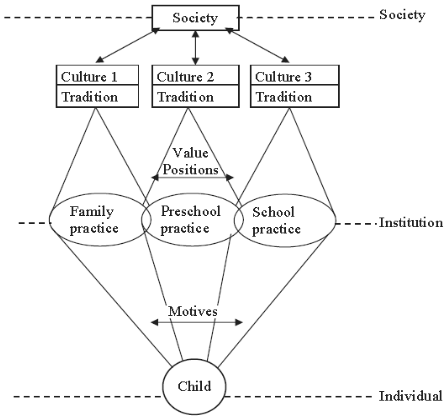

Figure 2. A model of child's learning and development through participation in institutional practice (Hedegaard, 2009, p. 73).

Overall, we propose that the framework provided by activity theorists is a coherent theoretical framework which establishes science education as participation in the community. Moreover, CHAT addresses the gap between theory and praxis. Also, it could achieve the scope of interdisciplinary science education in multicultural Europe. Consequently, a new mentality, which sees situated science education as part of society, has emerged. This could reform science education from its core, while lifelong learning activities take place in and for the community and for individuals as well.

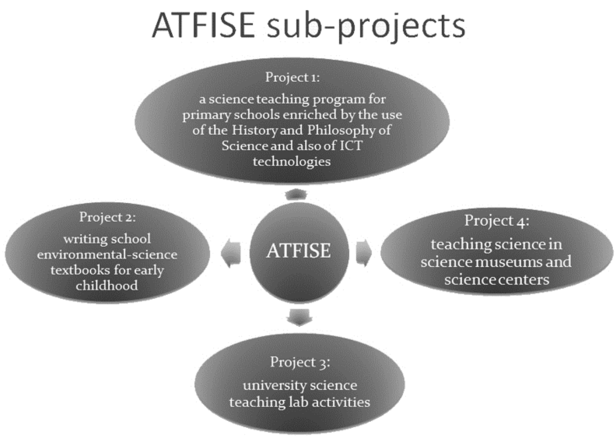

Figure 3. ATFISE subprojects.

We tested our proposal in four different settings: (1) a science teaching program for primary schools enriched by using the History and Philosophy of Science and

ICT technologies, (2) school environmental science textbooks for early childhood, (3) university science teaching lab activities, and (4) science museums and science centers. The ATFISE subprojects are represented in Figure 3.

In continuation, there is an introduction to each ATFISE subproject.

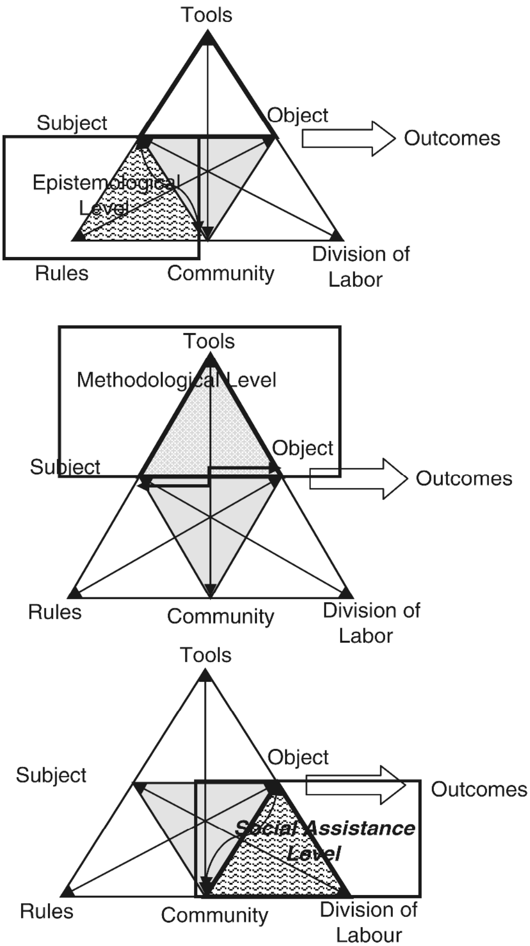

Figure 4. Three levels of activity analysis. Specific emphasis on Epistemological, methodological, and societal interactional levels.

In Chapter 6, ATFISE subproject 1 uses CHAT to analyze and then design new ICT learning environments enriched by the History and Philosophy of Science, which are the prominent cultural mediation tools. It focuses on parts of Engeström's triangle[4] focusing either on the epistemological level (rules-subject-community), or the methodological level (tools, subject, object), and|or the societal interactions level (division of labor, object, community) (Figure 4).

In Figure 5 we see a web page for ATFISE subproject 1. A welcome page for children, introduces an interactive lesson, in which we used several teaching strategies enriched by the history of science.

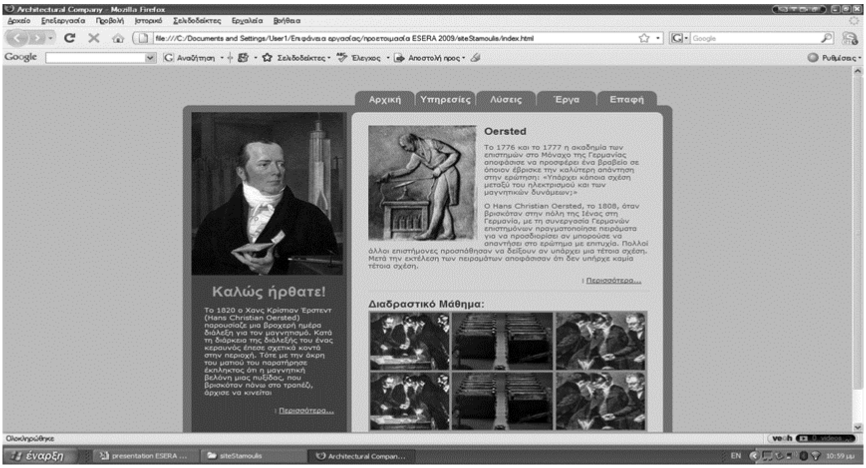

Figure 5. A web page for Sub-Project 1 (photo from editor's/author's archives).

To develop teaching activities, we employ Engeström's (1987) conceptual tool of the expansive cycles. In Figure 6 we use Engeström's (1999) descriptions of the "ideal-typical sequence of learning actions." In Chapter 6, we expand this idea by using expansive cycle as a tool for designing activities for primary science education.

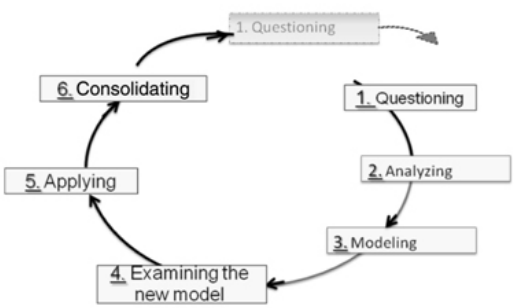

Figure 6. Expansive cycle (Engeström, 1999, p. 383).

ATFISE subproject 2 (see Chapter 5 in this volume) was concerned with the development of school science curricula and textbooks for the first grade, as well as two environmental software programs for elementary schools. We tried to develop those materials in the sociocultural context, and for this reason we used salient cultural tools within and across multiple authentic learning environments (Figure 7).

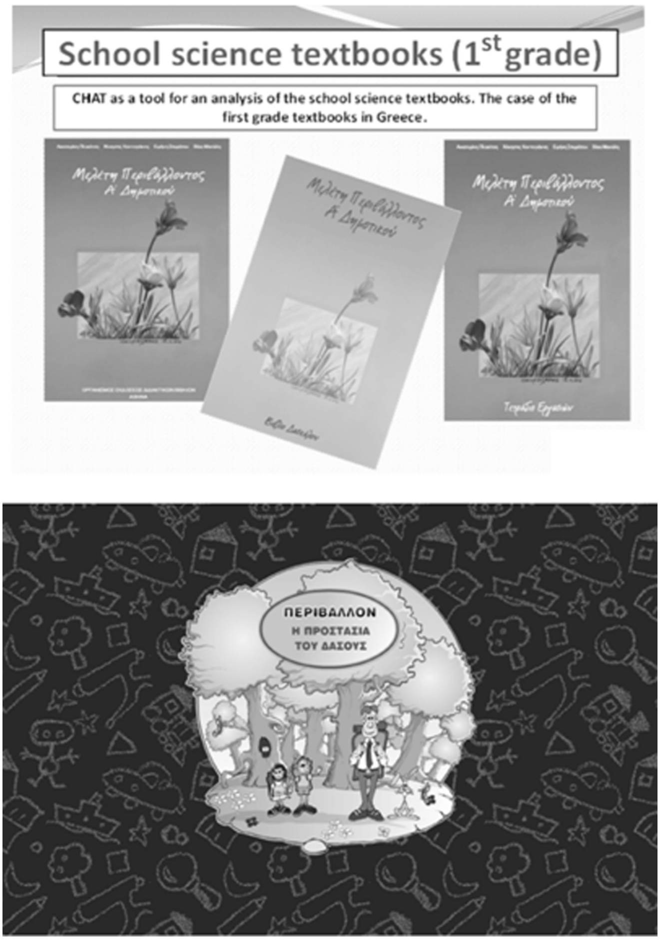

Figure 7. School science textbooks and software for first grade (photos from the editor's archives).

ATFSE subproject 3 (parts 1 and 2) was presented at the ESERA biennial meetings in 2009 and 2011 and is concerned with applying activity theory in university lab lessons, as well as using cartoons in teaching science in the early grades. The conspicuous cultural tools are the cartoon stories we wrote and projected in the classroom. While university students were working in the science lab, we recorded their dialogue exchanges and experimental practices and then we analyzed the group interactions according to Mwanza and Engeström's eight-step model (2003).

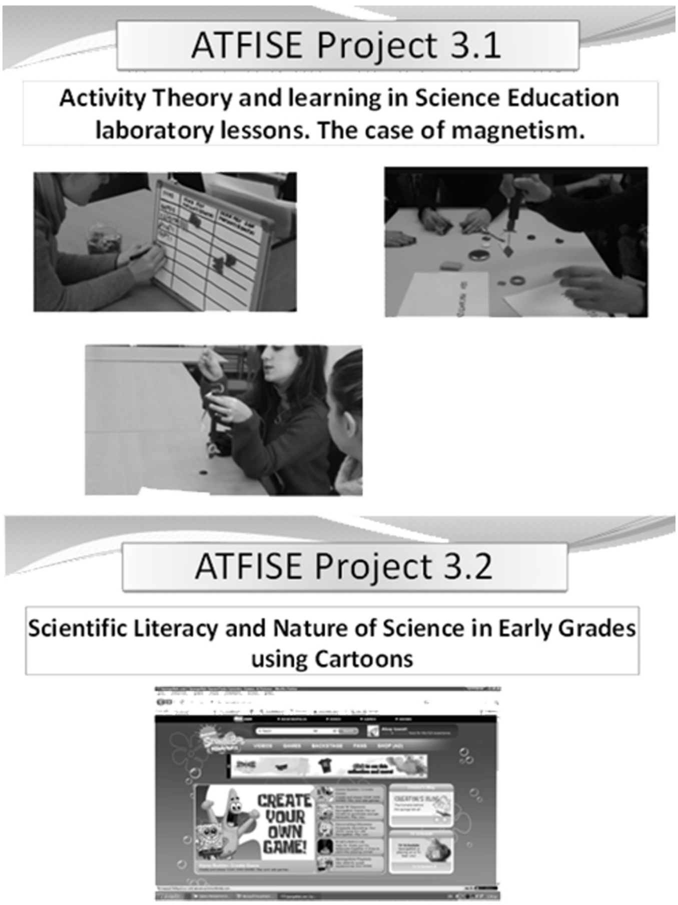

Figure 8. Project 3.1: Students/future teachers in early childhood experiment with magnets in science lab(photos from the editor's archives). Project 3.2 Future teachers use popular cartoons for teaching sinking and floating things (http://www.nick.com/games/spongebob-game-builder/).

ATFISE subproject 4 connects formal and nonformal astronomical learning. This project refers to an astronomy education program for preprimary and primary school students, which aims to develop a new science curriculum within museum education programs and introduces methodological tools from CHAT.

The placement of a museum piece, such as a mobile inflatable planetarium, inside a typical school allows us to explore interactions between formal and nonformal education, to experiment with new teaching processes using activity theory, and to track similarities and differences between our case and the usual situation, when the planetarium is a permanent installation out of the school.

Figure 9. Children in and outside the mobile planetarium (photos from the editor's archives).

Furthermore, we organized a Lifelong Learning Program (Erasmus Intensive Program) entitled LIGHT with the participation of seven European University Departments related to Cultural Studies of Science Education (http://erasmus-ip.uoi.gr).

During this interdisciplinary and multicultural project, university students were moving, for example, from the class to the lab and then outside to observe the night sky and then to the video seminar room.

In Figure 10 there is an example from the triangle analysis of the video seminar they conducted on the solar eclipse.

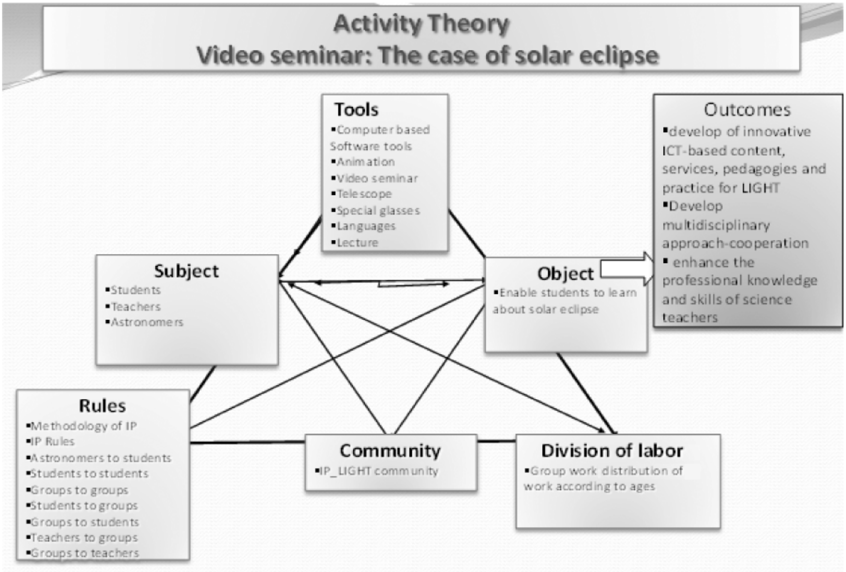

Figure 10. Triangular analysis of a video seminar on the total eclipse physical phenomenon (editor's archive).

The subjects were students, teachers, and astronomers who were involved in cogenerative dialogues (Roth & Tobin, 2004). The intensive program has rules established by the European Committee (e.g., to work at least 8 working hours per day), but the observation of the night sky had to be done after dusk, so all groups had to interact via other means and in a specific place outside. The community was strongly multicultural, with students and teachers from seven European countries, many religions (e.g., Christians and Muslims) and races (black and white), people from northern Europe and people from the Mediterranean. There were many tools, such as computer-based software tools, animations, video seminars, telescopes, special glasses, languages, and lectures. The goal was to enable students to learn about the total eclipse of the moon. The outcomes moved further, as the participants developed innovative ICT-based content, services, pedagogies, and practice about the properties of light. Finally, the development of such a multidisciplinary approach emphasized cooperation, and the enhancement of the professional knowledge and skills of science teachers.

In all mentioned subprojects, the main characteristics of the applied activities were the cultural profile of the learning environments, the cultural-historical references, and the cultural-historical means and methods of analysis. Our study belongs to the third generation of activity theory, which is concerned with understanding and modeling networks of activity systems.

The theoretical and methodological framework of analysis was the developmental approach of Yrjö Engeström (1987, 2005). Key elements of our methodology are those included in the Activity-Oriented Design Method (Mwanza & Engeström, 2003), and these are related to scientific studies on "human-computer interaction" (HCI) (Kuutti, 1996; Nardi, 1996).

Research on this interaction, using a nondualistic basis as an inseparable part of a learning-and-doing system, is much more than a challenge. We are going to adapt activity theory as a designing tool, in formal (schools) and informal (museums) science education sites, by using e-settings. This concept would advance the diffusion of a common European science learning culture. Modern schools and science museums in Europe organize many indoor and outdoor scientific activities based especially on e-learning technologies, but there is no common European science learning environment informed by CHAT, especially for young learners (5 to 9 years).

We collected data by using interviews, video-recordings and e-settings. All data are concerned with how science education is progressing in schools and labs (formal) and museums (informal). Specifically, as has been proposed in a number of studies (Roth and Tobin, 2005), our field research involves children, teachers, parents, and non-formal educators such as museum guides, etc

Our previous studies in the same research trajectory were (1) ontology, epistemology, and discursiveness in teaching fundamental scientific topics, (Plakitsi & Kokkotas, 2010); (2) reflective, informal, and nonlinear aspects of argumentation in school practice (Plakitsi & Kokkotas, 2007), (3) enhancing teacher education through interpretive-philosophical mediation about the nature of science: The MAP prOject (Plakitsi & Kokkotas, 2006), and (4) discourse analysis (Piliouras, Plakitsi, & Kokkotas, 2007).

We also organize biennial national conferences in science for early childhood as well as biennial winter sessions for PhD candidates (Figures 11 and 12).

The former and the latter studies and academic activities show that we try to organize modern aspects of science education in a fruitful theoretical context that could push the theoretical and practical research in science education forward. This valid theoretical context with the dynamic characteristics of interactive systems of activities could be the CHAT context.

Overall, CHAT seems to be a coherent theoretical framework which can achieve the scope of real scientific literacy, enhance interdisciplinarity in Europe, and develop a new mentality that could reform science education from within.

The ATFISE PROJECT belongs to the third generation of activity theory, which is concerned with understanding and modeling networks of activity systems. The theoretical and methodological framework of analysis is the developmental work approach of Yrjö Engeström (1987, 2005). People participate in multiple activity systems within their local and global contexts, including online. International collaboration is an activity system that is also embedded within broader institutional, historical, and geopolitical contexts. A person engaged in one activity system is simultaneously influenced by other activity systems in which she or he participates. These influences both horizontal, happening across communities, and vertical, as social actions are also embedded within history, culture, and inequitable power relations that both influence the meaning, production, and shape of human activities. Within an activity system, all elements constantly interact with one another. Changes in the design of a tool may influence a subject's orientation toward an object, which in turn may influence the cultural practices of the community. Engeström (1987) called an activity system "a virtual disturbance-and-innovation-producing machine."

Figure 11. Biennial conference on science in and for early childhood with international participation (http://users.uoi.gr/5conns, webpage editor's archives).[5]

Figure 12. Biennial winter sessions for phd candidates in science education. (http://www.edife.gr, webpage editor's archives).

NOTES

1 http://www.pisa.oecd.org/pages/0,3417,en_32252351_32235731_1_1_1_1_1,00.html
2 See, for example, Jorde and Dillon (in preparation).
3 See Van Eijck and Roth (2007).
4 See Chapter 6 in this volume.
5 + Poster design Nikos Giotitsas, biologist and PhD student.

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2. CULTURAL-HISTORICAL ACTIVITY THEORY (CHAT) FRAMEWORK AND SCIENCE EDUCATION IN THE POSITIVISTIC TRADITION

Towards a New Methodology?

τὸ ἀντίξουν συμφέρον καὶ ἐ κ
τῶν διαφερόντων καλλίστην
ἁρμονίαν (καὶ πάντα κατ’ ἔριν
γίνεσθαι).
Ηράκλειτος

Opposition brings concord.
Out of discord comes the fairest harmony.
Heraclitus[1]

INTRODUCTION

Two prominent methodological traditions, the positivistic and CHAT, developed in parallel and affected two approaches or paradigms to teaching and research (Kuhn, 1962). In this chapter we go through some basic elements of the two major traditions and we try to argue for a new methodology in science education, especially for early learners.

Recently, Kincheloe and Tobin (2009) published an article entitled “The much exaggerated death of positivism.” From this rigorous study we selected some quotes in order to make our argument. It is true that in the twentieth century both psychology and education have been dominated by behaviorism, which is a form of empiricism as well as logical positivism. So, methodologically, and ….

> from a behaviorist perspective, psychology is an objective experimental branch of natural science with a theoretical goal of predicting and controlling behavior. There is almost a preoccupation with method as a means of replicating results, and thereby identifying reproducible outcomes. The sources of behavior are external, belonging to the environment. A defining characteristic of behaviorism is a rejection of introspection and consciousness. If mental terms or concepts are used, they are to be translated into behavioral concepts. Causal regularities, laws and functional relations that govern the formation of associations are identified through experimentation in order to predict how

K. Plakitsi (ed.), Activity Theory in Formal and Informal Science Education, 17–26.

behavior changes and the environment changes. (Kincheloe & Tobin, 2009, p. 516)

The epistemology of positivism identifies valuable knowledge as that which involves objective information that reflects the real world. Kincheloe (2009) has classified six epistemological (with ontological dimensions) positivistic assumptions. These are Formal, Intractable, Decontextualized, Universalistic, Reductionistic, and One Dimensional. In Table 1, we assign these assumptions one by one to some assumptions which can be used with a CHAT approach to the topic of time. These are also informed from Plakitsi's doctoral thesis, "The Child's Conception of Time and Its Implications in Understanding Fundamental Scientific Concepts. An Interdisciplinary Teaching Approach." The thesis belongs to a Piagetian perspective enriched by some multiplicity elements. In this section we attempt to show the potential for moving from the positivistic to CHAT paradigm. This development emerged because of the inappropriateness and inadequacy of the positivistic paradigm with respect to the whole pedagogical context in which science education occurs. Adapting CHAT to science education research, Table 1 provides a comparison of positivistic epistemology versus CHAT assumptions.

Table 1. Positivistic versus Cultural Historical Activity Theory epistemology.

Positivistic epistemology	***CHAT epistemology***
Formal We do research on the child's phenomenology of the world, the object, time, etc. We use standardized tests, reliable questionnaires produced by a particular standard methodology, which is similar in any scientific research. We follow a rigorous step-by-step analysis. We teach the reliable scientific methodology to students as a step-by-step standard procedure.	**Nonformal** We do research with many different methods, without neglecting different research forms and traditions, for example, some qualitative methods. Researching and teaching are planned and replanned according to local societal conditions and the current circumstances.
Intractable For example, in the case of a child's conception of time, we investigate only the conventional aspect of time, which reflects the Newtonian concept of one unique and uniform time in the universe. All other aspects of time are excluded from the research planning. Even if we know about relativistic time, we teach and/or do educational research on conventional time, as it is the unique aspect of time. Also, conventional time is considered as stable –	**Intractable** Scientific concepts and also childhood are considered as ongoing processes; the teaching/researching refers to some milestones of their evolution. Changes considered as the target point of the teaching/researching.

an entity existing outside the child, in the external world (e.g., clocks). Furthermore, we tend to teach relativistic time only in high school and at the university level, while we have developed students with the Newtonian aspect of time being unique and independent of scientific evolution. Additionally, we partially teach time as a psychological infralogical structure (Piaget, 1972). Finally, any ongoing temporal event is outside of typical teaching/ researching.	
Decontextualized We do research on children's conceptions of time independently from children's sociocultural, economic, family, and school environments. When we teach conventional time using clocks, usually we focus on the mechanical clock; children have to learn hours, minutes, and seconds the same way. Rarely, we consider that some children from rural regions may already know the passage of time and the main daytime hours through sundials, sun movements, etc. And it is also rare to begin with the history of clocks, e.g., from water clocks in Egypt, candle clocks, clepsydras, and the pendulum to the modern mechanical clocks and then to quartz clocks and so on. Furthermore, the very interesting story about pendulums (Matthews, 2000) can show the children that major political concepts (science only for the elite and not for the masses) and religious beliefs (the creator as a clock maker) have influenced the standard measures and weights we have now.	**Contextualized** We do research on chilrden's conceptions of time based on children's sociocultural, economic, family, and school environments. When we teach conventional time using clocks, children learn about time using their own pathways. We constantly take into consideration that some children from rural regions may already know a lot of temporal dimensions through rural activities. We recommend beginning with the history of clocks, e.g., from water clocks in Egypt, candle clocks, clepsydras, and the pendulum to the modern mechanical clocks and then to quartz clocks and so on. Furthermore, the very interesting story about pendulums (Matthews, 2000) can show the children that major political (science only for the elite and not for the masses) and religious concepts (the creator as a clock maker) have influenced standard measures and weights. Teaching/ researching is contextualized. Knowledge is always in context. Context analysis is important. Different contexts enrich teaching/ researching, interest, and challenge for change, while in the positivistic tradition different contexts cause research bias and teaching noise. Development is viewed as the ability of context transformation, and/or the movement from context to context, from system to system. There is teaching time, researching time, religious time, astronomical time, etc.

Universalistic The basic principle here is that teaching leads to one form of knowledge: a true and stable knowledge. Science is being taught as the discovery of true knowledge, which exists in the real world. This knowledge is external and outside of the children. So the universe, the environment acts upon the children, and they internalize the impacts of the environment. This decontextualization was a prominent perspective in education, but we now know that scientific "truths" – as one example, the field of physics – have evolved considerably.	**Multicultural** The central idea of this section is that there are many types of science, for example, western science, indigenous science, and personal science. Different ways of interpreting data lead to multiple world views that create unity from the differences. Time is one of example that shows how scientific paradigms (Kuhn, 1962) changed from one era to another. For example, Newtonian time is unique and uniform in the universe; the Kantian critique of pure reason supported this kind of scientific thought. Furthermore, no one teacher teaches anything about Bergson and his psychological aspect of time. The concept of time in Einstein's theory of relativity depends on the observer. Moreover, the conceptualization of time is totally different in quantum mechanics, where fundamental concepts such as "before" and "after" obtain a totally new meaning and where causality, as in classic physics, does not exist. Fortunately, the voices of great thinkers such as Popper and Kuhn reshaped modern scientific enterprise. Prominent psychologists such as Piaget also worked on the notion of time. In fact, we thus have various concepts of time: psychological, astronomical, and relative. Time has different meanings for Christians, Jews, Muslims, Buddhists, etc. Ultimately we have to accept that all kinds of time have scientific and cultural value.
Reductionistic This means that only one research method is the scientific one, and any researcher can repeat the same research results any place in the world by following the same method. During learning and teaching processes, we consider the achievement of the same objective as the one way to successfully orient an activity. The researcher's origins, studies, way of thinking and observing, and the	**Local** There is neither reductionist research nor one method of teaching because of the different forms of artifacts that mediate human activities. By keeping the local local, we can acquire a rich list of criteria, as well as ways of knowing and learning. We theorize that changes in systems of activities are successful and meaningful processes that occur during the activities. Change means

communities involved are from a positivistic research perspective. Objectivity and neutrality disguise the ethnocentric and colonial bias elements of research.	advancement. Succession of events means passage of time, and different ways of conceptualizing and measuring durations are approved.
Unidimensional Reality is unidimensional, so research on a child's conception of time therefore assumes the Western concept of time. Historically significant perceptions of time, such as those of the ancient Greeks (Parmenidis, Helakleitos, Plato, and Aristotle [Physics IV]) are excluded. Different meanings of time also exist among people of India, American Indians, and indigenous Australians. One voice is privileged. Multiple voices are opposed to the single correct scientific perspective. Even great modern researchers, who find language to communicate with general audiences about time according to quantum mechanics theory, adopt this perspective. Multiple voices are seen to threaten national security rather than a basis for reconceptualising national security as a unity of the different aspects.	**Multidimensional** Reality and environment are multi-dimensional and complex. We need new methodologies for teaching and researching in these interactive and progressive systems of relationships.

All epistemologies are explicit or implicit in any research planning or program. Teachers/researchers are often not conscious of their research bias. In this regard, Kincheloe and Tobin (2009) speak about "crypto-positivism."

> A central part of this crypto-positivism is adherence to a scientific method derived from the natural sciences and deemed necessary for a rigorous social science. (p. 514)

Positivism as logic for inquiry, and as a teaching background, can be considered as a part of a wider current of thought that reflects many colonial characteristics. This major tradition established the superiority of Eurocentrism, and is used to devalue other cultures using criteria of some encrusted prejudices. It is not fair to judge one culture by criteria from another. This practice promotes social exclusion while, as one example, the European Union made social inclusion a priority. Furthermore, some African, Indian, and Aboriginal cultures offer great benefits to western cultures, if the latter can make an effort to become familiar with indigenous knowledge.

Natural scientitists are familiar with Einstein's theory about different observers in different points of the universe and with the absolutely revolutionary ideas of modern quantum mechanics theory. Simultaneously, natural sciences gave their reliable and superior method to social sciences. Consequently, we wonder why we still remain loyal to positivist thinking. There can be many answers to this question, derived from religion, politics, and economics. All these domains influence scientists and researchers while they do their work. All these epistemological anatreptic voices have been recorded by great thinkers such as Popper (1969), in *Conjectures and Refutations,* and Lakatos (1978), in *The Methodology of Scientific Research Programmes,* as well as Feyerabend (1975), in his work *Against Method.* In the concluding chapter, the latter wrote:

> To sum up: there is no ‘scientific world view’ just as there is no uniform enterprise ‘science’ …. Still, there are many things we can learn from the sciences. But we can also learn from the humanities, from religion and from the remnants of ancient traditions that survived the onslaught of Western Civilization. No area is unified and perfect …. [p. 249, emphasis added]

Pluralistic epistemologies support that knowledge is a constant process of creation rather than the static phenomenon of positivistic thinking, instead of the positivistic treatment of knowledge as a static phenomenon. The epistemologies, ontologies, and multiple research methodologies we embrace understand that educational phenomena are situated in environments constructed by their temporal interactions with the other dynamics in the world (Tobin & Kincheloe, 2006).

Overall, in this complex situation where the teachers/researchers must follow multiple voices and traditions and where researchers must reject old research and tools of observation in order to change themselves, we need to begin a dialogue within all nations to develop multiscience education systems. Aikenhead and Ogawa’s clear description of the multiscience perspective (2007) is remarkable for its use of the words *science*, *knowledge*, *perceiving*, and *rational*.

> A rational perceiving of reality has three aspects: a process, a product (i.e., knowledge or action), and a cultural context defined by the people engaged in the perceiving. Ogawa (1995) considered three sciences: Eurocentric science, indigenous science, and personal science (a rational perceiving of reality unique to each individual, not discussed). (p. 544, brackets deleted)

Recapitulating, we need a different epistemology which will enable a shift from universalism to multiculturalism. Science curricula must include some traditional or indigenous forms of knowledge. Traditional ecological knowledge and typical science have been studied rigorously by van Eijck and Roth (2007). Concepts such as locality, multiculturalism, relativism, material reality, cultural reality, and plausibility have been deeply interpreted from a multicultural perspective. The authors prove the nonfeasibility of reductionism. Any type of nonwestern science fails to satisfy the criteria of good science because of the different frames of reference and the different relations with the material or the cultural reality (van Eijck & Roth, 2007, p. 931). Truth, knowledge, socialization, and enculturation are also discussed in this article. In fact, when structuring a curriculum, when making a project in schools, we must make choices—choices about the types of knowledge we shall use, rates of transition, and evaluating methods. All these are necessary epistemological options from a multiculturalism or universalism perspective. The authors argue for the heterogeneous character of knowledge as in the following quote:

> Knowledge, as integral to human being, is also a mêlée of voices, texts, procedures, tools, constructs, and so on; it exists only in and through its continuous production and reproduction in the concrete praxis of real human beings[2]. Even the most transcendental and deductive sciences, such as geometry, only exist in the dialectical relationship with human practices. As a continuous ongoing process subject to collective human practice, knowledge emerges and disappears as it is constructed and deconstructed, shaped and reshaped, produced and reproduced, forgotten and reminded, reinvented and taught. More so, even if we perceive knowledge as a body, as a singular identity in itself, it is so in the midst of other bodies of knowledge and therefore never on its own. In this sense knowledge is, like human bodies, singular plural in nature.[3] Consequently, knowledge also is essentially heterogeneous rather than homogeneous (van Eijck & Roth, 2007, pp. 932–933).

Accordingly, we need a different epistemology which treats reality both physically and culturally and incorporates the different types of knowledge as well as human practices by giving them the same value without superiorities and/or inferiorities. We propose that the framework provided by activity theorists is a coherent theoretical framework which establishes science education as participation in the community (Roth & Lee, 2004). Moreover, research on a nondualistic basis, as an inseparable aspect of a learning and doing system, is much more than a challenge. We are going to adapt activity theory as a designing tool for formal (schools) and informal (museums) science-education-places by using e-settings. This concept will advance the osmosis of a common European science learning culture. Modern schools and science museums in Europe organize many indoor and outdoor scientific activities based especially on e-learning technologies. In spite of all these efforts, there is no common European science learning environment informed by CHAT, especially for young learners (5–9 years old).

CULTURAL-HISTORICAL ACTIVITY THEORY

A New Paradigm

CHAT originated with Soviet thinkers who saw behaviorism and analytical psychology as unable to manage the material and cultural reality which was then on the scene. The concept of activity became very important in the societal setting, and the focus was on activity as the unit of analysis. Two kinds of activity element were distinguished: the cultural-historical and the material.

They studied activity mainly on the macrolevel, e.g., hunting, farming, constructing, building, producing. Human needs were at the top of the pyramid of social structures in a socialistic society. Accordingly, knowledge was a product, an outcome to be spread in the community, in which members/subjects act by dividing the work/labor and by following community rules and always using artifacts/tools. Tools might be mental, hands on, or simply a tool or machine.

The main role of the artifacts/tools is to mediate between subject and object. This mediation leads to outcomes that change society, the environment, and humans themselves. Thus, these social and environmental changes have reciprocal effects; social and environmental inputs require human accommodations and, in turn, human activities significantly influence the society and environment.

Knowledge also follows this schema of relations and is considered as part of object-oriented and artifact-mediated activity (Vygotsky, 1978). This schema imposed significant changes in scientific and teaching methodology. The unit of analysis is the activity, and the unit of learning community is the group. The focus was transferred from the individual to the system. The activity system became the central interactive unit with inputs and outputs. In this epistemology, one can find many similarities to the evolution and|or revolution of natural sciences. Dialectical relations form a scientific system as well as social activity systems. Dialectical relations between subject and object define activity (Roth & Lee, 2004; van Eijck & Roth, 2007).

Piagetian epistemology places individuals and their mechanisms of reasoning at its center. The prominent Piagetian method of clinical interview investigates the logical functions of individuals while excluding society from the interview settings. The teacher/researcher seems to examine an individual's reasoning or conceptualization a posteriori, that is to say, at the end of an individual's activity with the society or the environment.

Instead of this approach, CHAT inspired teachers/researchers to study human learning as being human (biological, evolutional), belonging (societal and environmental), and becoming (societal and environmental) (Lee and Roth, 2003). Without a priori axioms a new epistemology emerged: an epistemology of Being and Time, as Heidegger proposed (Heidegger, 1982, 1992). In CHAT, knowledge is always in context. This context gives meaning to the artifacts.

With the passage of time, artifacts become better and better, while human experience with their use in turn reshapes artifacts. Then, the elaborated artifacts modify or totally change the activity in an eternally ongoing process. History and culture form scientific activities, which in turn change history and culture and vice versa in a dialectical way of being and uniting the opposites, as articulated by Heraclitus in his doctrine of change: Opposition brings concord. Out of discord comes the fairest harmony (Heraclitus, fragment 98).

Roth and Lee (2007) argue that CHAT allows us to approach and analyze typical activity systems (praxes, contexts). The activity systems can be, for example, science, environmentalism, and indigenous knowledge systems.

At the macrolevel, when moving from actions to activity, we have expansive learning (Engeström & Sannino, 2010). The theory of expansive learning focuses on learning processes in which the very subject of learning is transformed from isolated individuals to collectives and networks (p. 5). Expansive learning is manifested primarily as changes in the object of the collective activity (p. 8).

Boundary crossing involves collective concept formation (p. 12). Expansive learning takes place because historically evolving contradictions in activity systems lead to disturbances, conflicts, and double binds that trigger new kinds of actions among the actors (p. 18).

In conclusion, we argue that it is obvious that we need a new methodology in/for teaching and researching. Maybe we can start with concepts such as "communities of practice," "collaborative planning," "learning communities," and "socioemotional learning," which are enabled in many modern school curricula. We have also to work on new values. Whether the current public schools continue to have a monolithic and deterministic bias or whether new dialogues will emerge and create novel institutional structures depends upon our efforts. A current article by Jahreie and Ottesen (2010) discusses "third spaces" and "learning spheres." These articles, and the very important schema of Marianne Hedegaard (2009) (see Chapter 1), move the discussion beyond Engeström's triangle of activity. We can do educational research in different local settings and keep the local local. Also we can study children acting through participation in different institutions and contexts. Finally, we can focus learning spheres in order to study knowledge acquisition. We must change ourselves in order to study changes in social, environmental, and personal systems of activities.

NOTES

[1] Fragment 98, as translated by Philip Wheelwright, in Wheelwright, P. (1966). *The Presocratics*. Indianapolis: ITT.

[2] See Chapter 7 entitled: In praise of the mêlée. Toward a new conception of scientific identity and literacy. The chapter is published in the book: Roth, W.M., van Eijck, M., Reis, G., & Hsu, P-L. (2008). *Authentic Science Revisited.* Rotterdam: Sense.

[3] Roth, W-M. (2006). *Learning science: A singular plural perspective*. Rotterdam, The Netherlands: Sense Publishers.

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