KATERINA PLAKITSI

1. ACTIVITY THEORY IN FORMAL AND INFORMAL SCIENCE EDUCATION

The ATFISE Project

INTRODUCTION

The 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

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

third-world countries, while science approaches in European countries may differ 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 (Engestrom, 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 (Engestrom, 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.

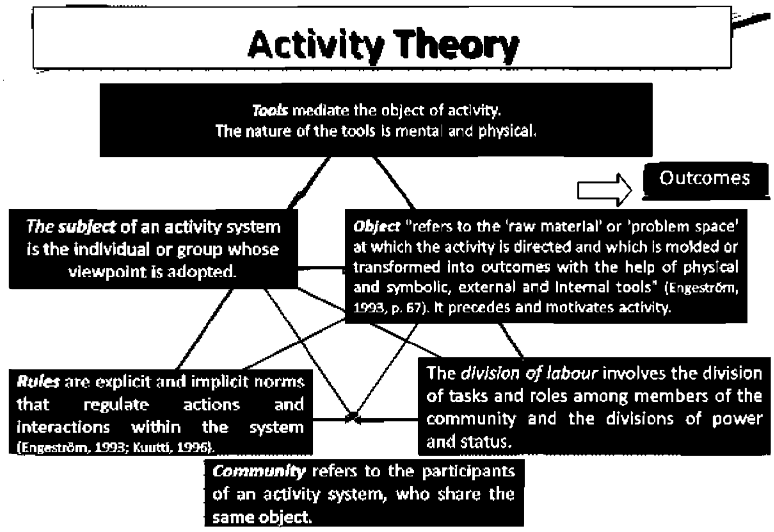

Figure 1. Components of the activity system (Engeström, 1987).

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 and 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 and 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.

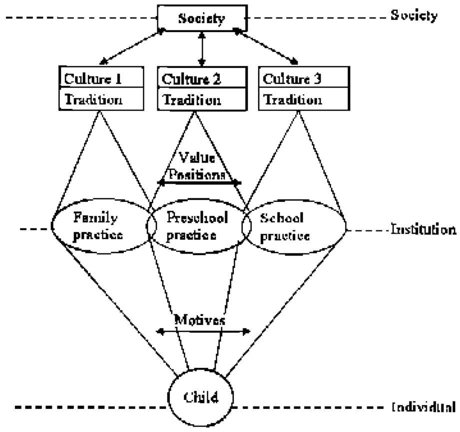

Figure 2. A model of child's learning and development through participation in institutional practice (Hedegaard, 2009:73).

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.

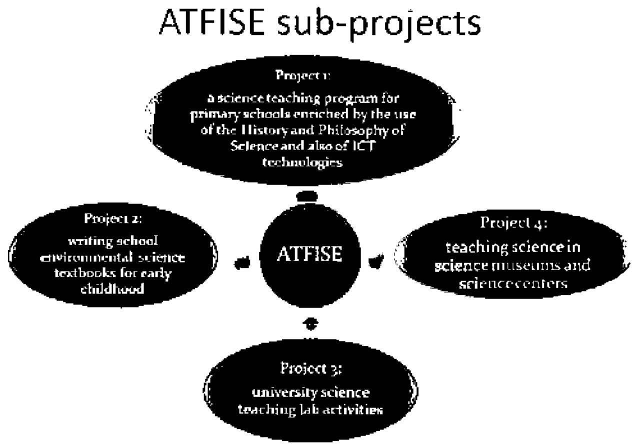

Figure 3. ATFISE subprojects.

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.

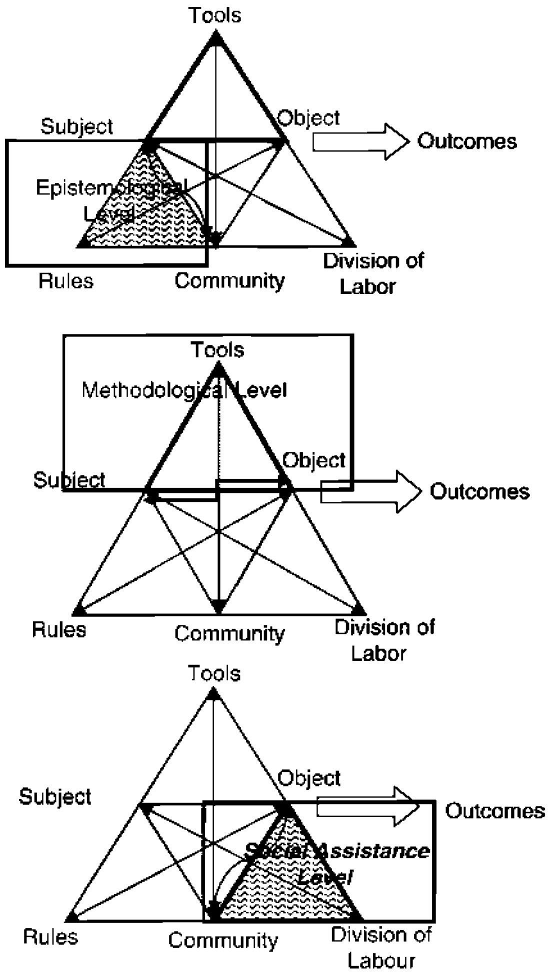

Figure 4.Three levels of activity analysis. Specific emphasis on Epistemological, methodological, and societal interactional levels.

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) (Fig. 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.

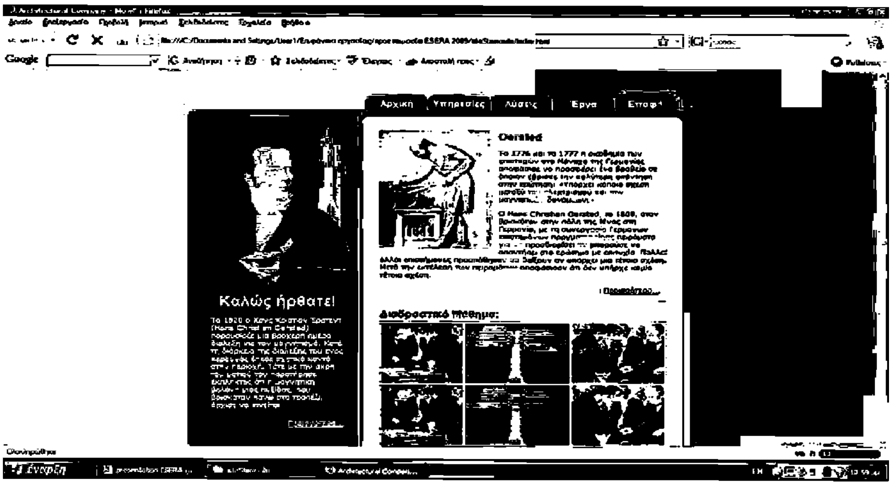

Figure 5. A web page for Sub-Project 1 (photo from editor's/author's archives).

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.

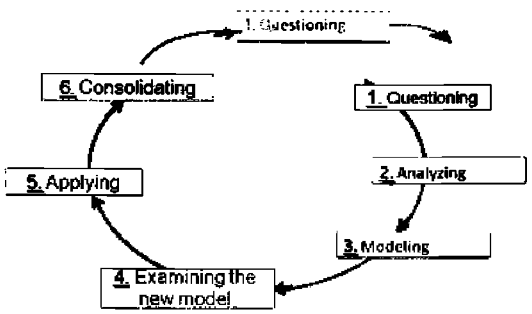

Figure 6. Expansive cycle (Engeström, 1999:383).

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 (Fig. 7).

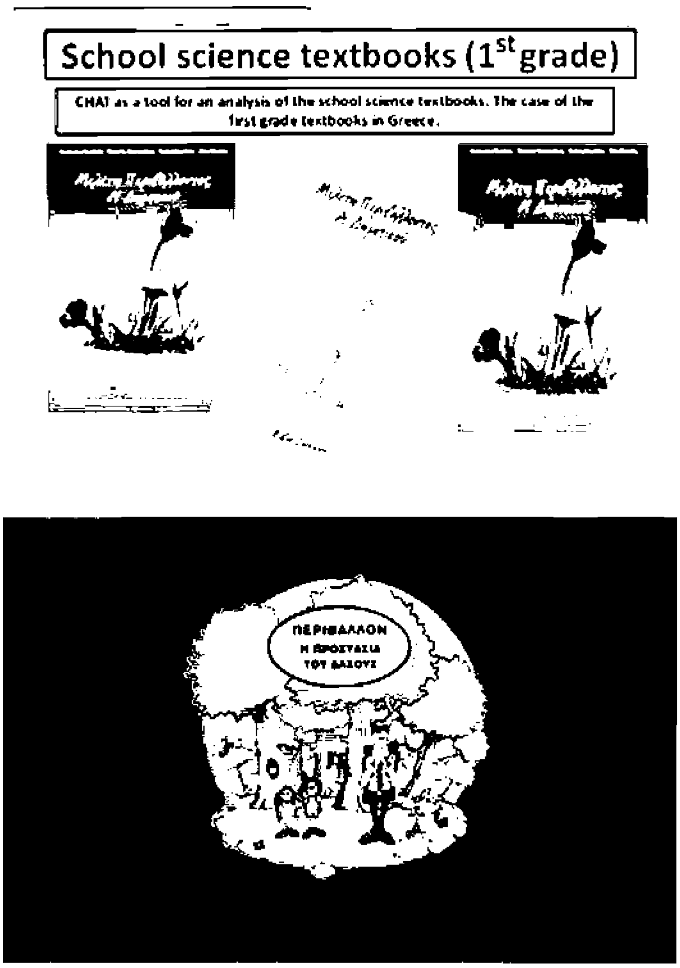

Figure 7. School science textbooks and software for first grade ((photos from the editor's archives).

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).

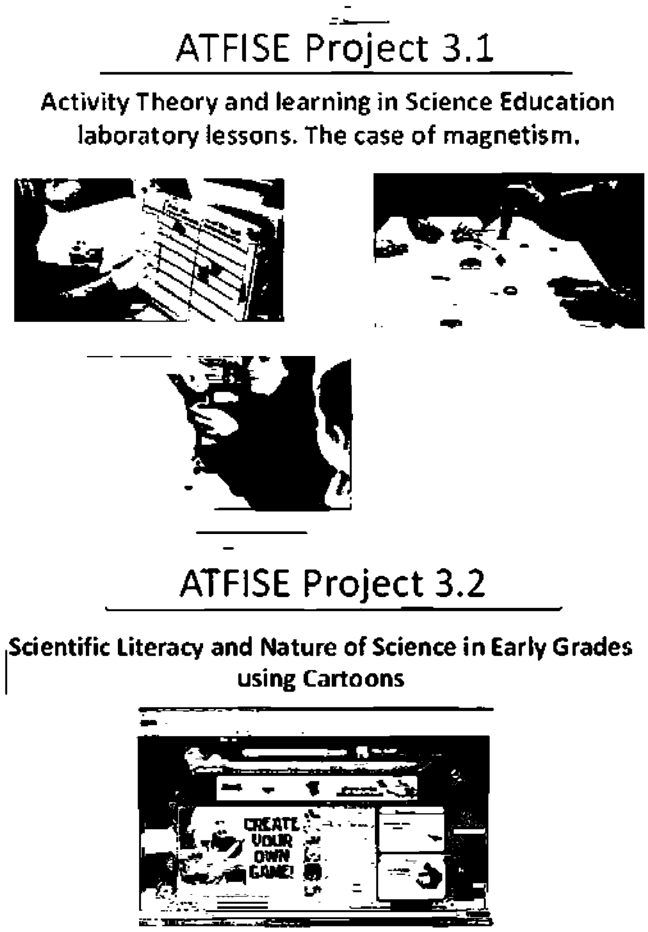

Figure 8. Project 3.1: Students/future teachers in early childhood experiment with magnets in science lab(photos from the editor's archives). Project 3.2 Future teachers use popular cartoons for teaching sinking and floating things (http://www.nick.com/games/spongebob-game-builder/).

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.

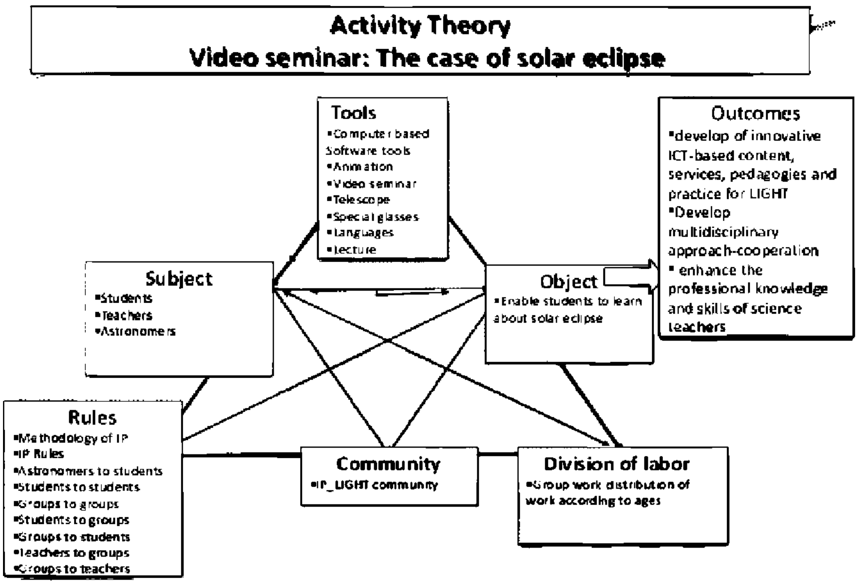

Figure 10. Triangular analysis of a video seminar on the total eclipse physical phenomenon (editor's archive).

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 and 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. (Fig. 11 and Fig. 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 & Dillon, (eds.), in preparation.
3 See: Van Eijck, M., Roth, W. M. (2007). Rethinking the Role of Information Technology-Based Research Tools in Students' Development of Scientific Literacy. *Journal of Science Education and Technology,* 16, 3, 225–238.
4 See Chapter 6 in this volume.
5 + Poster design Nikos Giotitsas, biologist and PhD student.

REFERENCES

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research.* Helsinki, Orienta-Konsultit, Oy.

Engeström, Y. (1993). Developmental studies of work as a testbench of activity theory: The case of primary care medical practice. In S. Chaiklin & J. Lave (Eds.), *Understanding practice: Perspectives on activity and context* (pp. 64–103). Cambridge, MA: Cambridge University Press.

Engeström, Y., Miettinen, R. & Punamaki R. (Eds.) (1999). *Perspectives on activity theory.* New York: Cambridge University Press.

Engeström, Y. (1999). Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. In Y. Engestrom, R. Miettinen, & R. Punamaki (Eds.), *Perspectives on activity theory.* New York: Cambridge University Press.

Engeström, Y. (2005). *Developmental work research: Expanding activity theory in practice.* Berlin: Lehmanns Media.

Fleer, M., & Hedegaard, M. (2010). Children's development as participation in everyday practices across different institutions. *Mind, Culture, and Activity, 17*(2), 149–168.

Hedegaard, M. (2009). Children's development from a cultural-historical approach: Children's activity in everyday local settings as foundation for their development. *Mind, Culture, and Activity, 16*, 64–82.

Jorde, D. & Dillon, J. (Eds.). (in preparation). *A handbook of science education in Europe.* Rotterdam: Sense.

Kaptelinin, V., & Nardi, B. (2006). *Acting with technology: Activity theory and interaction design.* Cambridge: MIT Press.

Kaptelinin, V., Nardi, B. A., & Macaulay, C., (1999). The activity checklist: A tool for representing the "Space" of context, ACM /Interactions. *Methods & Tools, 6*, 27–39.

Lantolf, J. (2006). Sociocultural theory and L2: State of the art. *Studies in Second Language Acquisition, 28*(1), 67-109.

Plakitsi K., & Kokkotas, V. (2010). Time for education: Ontology, epistemology and discursiveness in teaching fundamental scientific topics. *AIP Conference Proceedings, 1203*, 1347–1353. This paper was based on a presentation to the 1st International Conference of International Society for Cultural and Activity Research (I.S.C.A.R.), Seville, Spain, 2005.

Kravtsova, E. E. (2006). The concept of age-specific new psychological formations in contemporary developmental psychology. *Journal of Russian and East European Psychology, 44*(6), 6–18.

Kuutti, K. (1996). Activity theory as a potential framework for human-computer interaction research. In B. Nardi (Ed.), *Context and consciousness.* London: MIT Press.

Mwanza, D., & Engeström, Y. (2003). Pedagogical adeptness in the design of e-learning environments: Experiences from the Lab@Future project. In *Proceedings of e-learn 2003: International conference on e-learning in corporate, government, healthcare, and higher education* (Vol. 2, pp. 1344–1347). Phoenix, AZ..

Nardi, B. A. (1996). Activity theory and human-computer interaction. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 69–103). Cambridge and London: MIT Press, .

OECD. PISA 2006 results. Science Competencies for Tomorrow's World (2 Vols.).

Piliouras, P., Plakitsi, K., & Kokkotas, P. (2007). Sofia doesn't speak during team work. Using discourse analysis as a tool for the transformation of peer group interactions in an elementary multicultural science classroom. Paper presented to 12th biennial conference for Research on Learning and Instruction, EARLI 2007, Budapest, Hungary.

Plakitsi, K., & Kokkotas, V. (2006). Enhancing teachers' education through interpretive-philosophical meditation about the nature of science: The MaPrOject. Paper presented to the Joint North American –

European and South American (N.A.E.S.A.) Symposium *Science and Technology Literacy in the 21st Century*, May 31–June 4, 2006, University of Cyprus. Proceedings, Vol. 1, pp. 200–211.

Plakitsi, K., & Kokkotas, V. (2007). Reflective, informal and non-linear aspects of argumentation in school practice. Year book of School of Education, University of Ioannina, B: 199-213.

Rogoff, B. (2003). *The cultural nature of human development*. Oxford, UK: Oxford University Press.

Roth, W. M., & Tobin, K. (2004). Cogenerative dialoguing and metaloguing: Reflexivity of processes and genres [35 paragraphs]. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 5*(3), Art. 7. Retrieved from http://nbn-resolving.de/urn:nbn:de:0114-fqs040370

Roth, W.-M., & Tobin, K. (Eds.). (2005). *Teaching to-gether, learning together*. New York: Peter Lang.

Roth, W.-M., Lee, S. (2004). Science education as/for participation in the community. *Science Education, 88*(2), 263–291.

van Eijck, M., & Roth, W.-M. (2007). Keeping the local local: Recalibrating the status of science and Traditional Ecological Knowledge (TEK) in education. *Science Education, 91*, 926–947.

van Eijck, M., & Roth, W. M. (2007). Rethinking the role of information technology-based research tools in students' development of scientific literacy. *Journal of Science Education and Technology, 16*(3), 225–238.

Vygotsky, L. S. (1998). *The collected works of L. S. Vygotsky* (M. J. Hall, Trans., Vol. 5, Child Psychology). New York: Kluwer Academic/Plenum.

Katerina Plakitsi
School of Education
University of Ioannina
Greece
kplakits@cc.uoi.gr