# A Cultural Historical Activity Theory Approach In Natural Sciences Education Laboratory Lessons Towards Reforming Teachers Training

Eleni Kolokouri
Department of Pre-school Education, University of Ioannina
19 Dimitriou Kostaki Street, Ioannina 45221, Greece
Tel: 30-694-296-1651 E-mail: ekolokouri@gmail.com

Xarikleia Theodoraki
Department of Pre-school Education, University of Ioannina
3 Evergeton Street, Pireaus, Greece
Tel: 30-694-857-7400 E-mail: xarikleia85@hotmail.com

Katerina Plakitsi (Corresponding author)
School of Education, University of Ioannina
University Campus Dourouti 45110 Ioannina, Greece
Tel: 30-697-289-8463 E-mail: kplakits@cc.uoi.gr

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**Abstract**

This paper focuses on connecting natural sciences education with Cultural Historical Activity Theory (CHAT). In this sense, natural sciences education is considered as a lifelong learning procedure, not seen as an individual but as a collective activity. Moreover, learning becomes a human activity in which theory and praxis are strongly connected and learning outcomes are obviously seen in society and culture. The paper is a review of five years research on natural sciences education from a CHAT perspective in the Department of Early Childhood Education in the University of Ioannina, Greece. Effort is put on using CHAT as a theoretical framework in order to analyze and design natural sciences education activities. In this regard, teaching natural sciences in a university laboratory becomes a dynamic activity system which involves multiple participants (university teachers, lab assistants, students, early grade pupils etc.). All the participants act towards some common goals, considering scientific knowledge as cultural, historical and social process and using meditative and analyzing tools. Scientific concepts are taught as part of the natural curriculum of natural sciences education at the early grades which is strongly connected with CHAT. At this level scientific learning is connected with inquiring in authentic environments, practicing skills of observation, classification, communication etc., and making sense of the relations and interactions that take place in the world around us. The research question addressed in this paper is to highlight some qualitative dimensions of the socio-cultural aspect of teaching natural sciences in the early grades. Research data have been collected during practical application of lab activities in the early childhood classrooms by observing, video recording, interviewing and analyzing. This part involves university teachers, lab assistants, students, early childhood teachers, early grade pupils who work as a community towards reforming of natural sciences education.

**Keywords:** Cultural Historical Activity Theory, Natural sciences education, Early science, Lab activities, Teachers training

## 1. Introduction -Theoretical Framework

This paper focuses on connecting Natural Sciences Education with Cultural Historical Activity Theory (CHAT). It is part of the Cultural Historical Activity Theory in Formal and Informal Science Education (ATFISE) research project which takes place in the University of Ioannina, Greece and focuses on applying Cultural Historical Activity Theory (CHAT) in formal and informal science education, rethinking scientific literacy as well as the role of Information and Communication Technologies. Moreover, it heads towards teaching science education in an interdisciplinary and a multicultural dimension. In this sense, Natural Sciences Education is considered as a lifelong learning procedure, not seen individually but as a participation in the community (Roth& Lee, 2004).

The ATFISE research project is divided to four different sub-projects: a) a science teaching program for primary schools enriched by the using of the History and Philosophy of Science and also of ICT technologies, b) writing school environmental-science textbooks for early childhood, c) university science teaching lab activities, d) teaching science in science museums and science centers. The main characteristics of the nature of all the sub-projects are the socio-cultural dimensions of the learning environments, the cultural – historical references, and the CHAT means and methods of analysis.

CHAT is a theory with expanding applications in the field of natural sciences education in early childhood. The students collectively act in a community in the context of rules that the entire community follows. They become engaged in natural sciences activities and they use tools in order to deal with a scientific concept. Thus, the construction of knowledge becomes meaningful for students who interact with one another as well as with tools and means into the community of learners (Engeström, 1999). Moreover, learning becomes a human activity in which theory and praxis are strongly connected and learning outcomes are obviously seen in society and culture. The ATFISE research project concentrates on transferring CHAT into the fields of science education. As it is combined with other relevant case studies, it finally aims to validate CHAT as an evaluation tool of scientific activities in different learning environments and institutions, such as in the university laboratory, in the school classroom, in a museum or science centre etc.

Under the prism of CHAT learning involves a qualitative change of actions that may take place when people participate in meaningful cultural activities and receive scaffolding for improving of actions towards an inspiring object into the whole activity system. CHAT as well, helps us to design and develop natural sciences activities close to pupils' prior knowledge, which usually follows the rules and uses the artifacts of the Traditional Ecological Knowledge (TEK) of the local community. Thus, according to Eijck & Roth (2008), we try to justify that although science and TEK are both forms of human knowledge, the artifacts of these forms of knowledge are irreducible to each other, and thus, these forms of knowledge also are incommensurable with each other (p.935). Consequently, we tend to use a different epistemology that is multiculturalism versus universalism (Eijck & Roth, 2008, p. 930-933).

CHAT, with the prevalent idea of the activity system, can grasp the gap and hold multi cultural approaches among the interactive activity systems. In this regard, including both forms of knowledge in the scientific teaching leads to the production of context knowledge, which is relevant to the students' daily lives. Consequently, it will be a matter of choice about the level of science and TEK knowledge teachers might reach in their classroom, according to the students' concerns and problems that they encounter within their socio-cultural background.

In recent decades, many researchers in the United States, Canada and Europe have developed new theoretical foundation and research methods on the Theory of Activity, but the policies of European nations prove that the emerging agenda is isolated. However, crucial issues such as "learning communities", the "motivation to learn" and "quality of Natural Science research" are the most important topics in recent European Research magazines, conferences and books.

Studying the results of PISA 2009 (Programme for International Student Assessment) highlights the need for a new more fruitful framework to achieve the goal of scientific literacy and science education. This could be achieved by using Cultural Historical Activity Theory (CHAT). We stress the importance on the possibility of CHAT theory to bridge the gap between theory and praxis. It can also achieve the goal of interdisciplinary education in science education in the context of multicultural Europe. Therefore, a new mentality is emerging in science education as a social process. This could reshape education in Natural Sciences from the inside with a natural and logical manner in the context of lifelong learning.

The paper is a review of five years research on natural sciences education from a CHAT perspective in the Department of Early Childhood Education in the University of Ioannina, Greece. Effort is put on using CHAT as a theoretical framework in order to analyze and design natural sciences education activities. The ongoing research takes place within the frame of a university course entitled 'Didactics of Natural Sciences' which includes some lectures joined with a series of laboratory lessons of natural sciences activities. The research question addressed in this paper is to highlight

some qualitative dimensions of the socio-cultural aspect of teaching natural sciences in the early grades. In other words:

1. Does CHAT into the context of natural sciences education help university students become capable of teaching natural concepts in the early grades?

2. Is Chat a theoretical framework suitable for meaningful learning and scientific literacy development?

**2. Rationale**

University education has an internal structure, in which a course of science education in|for early childhood is the basic unit of the BA Degree in teaching for the early grades (Roth, Goulart, Plakitsi in press). The lectures on theoretical issues, the seminars, the laboratory lessons and the classroom applications are considered as a whole that allows us to understand the significance and the content in early childhood science education. Between the science course of university education and its components such as a laboratory lesson there is a whole-part relationship. The whole is understood through its parts, but the parts are understood through their relationships with and to the whole. The significance of a practical application can only be understood when we think of it not alone but through the structural positions that the practical application (parts) take in the science course (whole).

In this framework, prospective teachers need to receive professional training in order to teach natural sciences in the early grades. Teacher training in the university has to prepare them adequately for their actual classroom teaching, and make them capable of bridging the gap between theory and practice within the frame of science education. Furthermore, prospective teachers need to adopt suitable didactic strategies for introducing the content knowledge and applying didactic transformations. The development of the individual within the learning communities, the awareness of the teacher competences and the life skills that pupils must develop within their science education are also key elements for prospective teachers' training.

Great importance is stressed on the socio-cultural aspect of teaching natural sciences in the early grades as a means to reform natural sciences education. In other words, the use of CHAT into the context of natural sciences education provides motivation to prospective teachers to develop innovative natural sciences activities for their pupils and help them to teach natural concepts in the early grades. Thus, CHAT will become a theoretical framework suitable for analysis and designing activities from the field of science education and will achieve meaningful learning and scientific literacy development. Using CHAT in their training prospective teachers will study in depth and will analyze the interactions that occur within learning communities. In particular, they will explore the social identities of their pupils and the subjective perceptions of their own activity and their role in it. All in all, by using basic principles of CHAT in the science university course prospective teachers will consider development of scientific knowledge as a process of internalization from the society to the individual.

**3. Purpose**

The aims of this research project were set under a CHAT perspective in which scientific knowledge is a dynamic activity system and the participants, the institutions, the methods, the tools, the objects are connected in a cultural, historical and social process. Moreover, scientific knowledge overcomes its individual identity and becomes a collective activity with applications in science and society. Application of CHAT is regarded as an evaluation tool of scientific activities in different learning environments, as it is the school classroom, the laboratory etc. In this sense, aims can be adapted in several cases according to the demands of the community. Within the CHAT frame, the crucial role of this study is to define the kind of tools the subjects use to achieve their objectives and in what way, the rules that affect the way the subjects achieve the objectives, the influence of the division of labor and finally the rules that affect the way the community satisfies their objectives.

More specifically the study seeks to:

1. Use Cultural Historical Activity Theory (CHAT) as a theoretical framework in order to design and analyze natural sciences education activities.

2. Create the learning environment so that teachers and prospective teachers can develop innovative science activities for their pupils.

3. Provide prospective teachers the foundation for designing activities that are related to the socio cultural background of the early grades pupils.

4. Provide prospective teachers the opportunity to obtain key competences and skills necessary to teach in the early grades.

5. Develop positive attitudes and values towards Natural Sciences.

6. Contribute to scientific literacy and decision making of prospective teachers.

**4. Structure of the University Laboratory Lessons**

In the Department of Early Childhood Education, in the University of Ioannina, prospective teachers are trained to teach scientific concepts to the early grades within the university course Didactics of Natural Sciences I and II. The course lasts two academic semesters and includes a series of lectures and seminars as well as laboratory lessons on specific scientific issues.

The lectures take place in the seminar room of the Department of Early Childhood Education and cover a variety of topics necessary for the theoretical background of prospective teachers. Theoretical issues are connected with the significance of science education in early childhood, learning theories for science education, basic principles of the nature of science, methodologies of teaching science in early grades, development of skills of scientific method under the appropriate didactical transformation, early science curricula from all over the world and discussions about socio-scientific issues. Seminars are held by external collaborators or researchers who are called to interact with university teachers and students while presenting their theoretical views and case studies or research work. Even in the theoretical part, great importance is placed on considering science education as a matter of collective activity with applications and connections to society.

The laboratory lessons take place in a multiple activities room under the responsibility of the university teacher, the lab assistant and the Phd students. The contents of these lessons are connected with the Greek National Curriculum for the early grades which is under reforming. At this level scientific learning has been put on a cultural- historical and social basis. It is connected with inquiring in authentic environments, practicing skills of observation, classification, communication etc. and making sense of the relations and interactions that take place in the world around us.

The topics and concepts of the curriculum are related to the socio cultural background of the early grades pupils. In general, the topics include: human life, the surrounding environment, social structures and relations, life of plants and animals, natural phenomena etc. (Greek National Curriculum for the early grades, 2003). One of the central goals is to make pupils understand the relations and interactions that exist in the world we live by engaging them in proper activities. Pupils are considered as a member of a family, of a neighbourhood, of a community in the village or city they live in (p. 4, Greek National Curriculum for the early grades).They lead their life in a socially organized community with all the offers, demands and conflicts they meet under the influence and protection of their family. According to Hedegaard (2009), neither society nor its institutions (i.e., families, kindergarten, school, etc.) are static; rather, they change over time in a dynamic interaction between a person's activities, institutional practice and societal traditions. When the pupil enters the school institution (classroom) for the first time, he comes face to face with another socially organized environment in which he has to adapt through participating in everyday activities. The role of the teacher is that of a mediator who has to take into consideration all the different cultures in a classroom and thus facilitate the learning procedure in a pedagogical, interactive, and discursive atmosphere.

Within this frame, a variety of topics is introduced in the laboratory lessons, which are connected to problems and issues that early grade pupils encounter in their daily lives. Thus, the topics concern: plant collections, solubility of solids in water, floating and sinking materials, the human body, light-shadows-colors, electricity, sound, time, endangered species. The duration of each laboratory lesson is two hours and the materials used are both materials of pure science and everyday materials which can be found in a school classroom. A variety of didactic strategies is used during the laboratory lessons which include educational drama, pantomime, cartoons, games, etc. all of which follow the basic principles of CHAT (group work, use of instrumental and conceptual tools, interactions between subjects, mediation between subjects and community).

At the beginning, there is an introductory phase in which the students investigate about which scientific concept or phenomenon they are going to work on. They discuss about it in the laboratory, look for more information on the topic and share their experience in groups. Then, they set aims and design a project an order to reach the topic or deal with a problem. The project usually contains simple experiments, discussions, argumentations and suggestions to design classroom activities for pupils in the early grades. The laboratory lessons are not hand outs that can be applied in every classroom situation. They provide suggestions in order to help university students design their own classroom activities taking into account the different societal contexts of the learning environment.

The inquiry based method and the experiential way of working and interacting in the laboratory offers prospective teachers the opportunity to design scientific material suitable for different learning communities using scientific tools, skills, attitudes and values. Evaluation comes as a physical and logical procedure, for in the form of reflection and feedback as well as well development of metacognitive skills. Finally emphasis is put on the key competences that prospective teachers need in order to teach scientific concepts in a school classroom and on the life skills that children should develop through their education in science.

At the end of the laboratory lessons prospective teachers apply a series of science activities in pre-primary school classrooms. The teaching plan for prospective teachers is to use the basic principles of CHAT in order to have an active role in designing natural sciences activities in the laboratory lessons. They work in pairs in order to design their classroom material on a topic and teach the scientific concept to a school classroom over the course of two weeks. As a result of this collective activity university students become engaged in designing natural sciences activities in a socio-cultural environment. This way they become able to adopt suitable didactic strategies for introducing the content knowledge in a pre-primary classroom and applying didactic transformations. Observation by external observers is conducted in order to record the evolution of the didactic strategies, the emergence of spontaneous ideas from pupils and the classroom interactions. Video-tape recording of the classroom activities provides material for discussion and evaluation of the teaching process. Finally, semi-structured interviews with the prospective teachers responsible for each classroom are conducted and offer another source of evidence in which apart from the questions answered, suggestions are made and solutions are proposed.

The schools in which the practical application is conducted are situated in the urban area of Ioannina and each classroom has about 20-25 pupils. In-service teachers of the schools collaborate with prospective teachers on providing all the relevant information about their science teaching program and the children's cultural and social background. In-service teachers are generally enthusiastic about exchanging views on scientific matters with both prospective teachers and the research team. Members of our research team play the role of the observant in order to record the evolution of the didactic strategies and the emergence of spontaneous ideas from pupils. The classroom activities are video-taped, photographs are taken and meetings are held at the end of each day in order to evaluate the process and prepare for the following session.

## 5. Methodology

The methodology used in working and interacting with the university students in a laboratory lesson is based on:

i) the framework of analysis by the view of Yrjö Engeström (2005),

ii) the eight-step model of Mwanza (2001),

iii) the cultural- historical approach by Marilyn Fleer and Marianne Hedegaard (2008,2010) about children's development in every day practices and

iv) the project 'The Fifth Dimension' implemented by Michael Cole and the Distributed Literacy Consortium (2006).

### *5.1 An Introduction to Designing Classroom Activities based on CHAT:*

**The case of electricity**

This laboratory lesson is an introductory course to the key elements of CHAT theory and provides university students the opportunity to analyze activities using basic principles of CHAT. In this sense, university students become acquainted with the context of CHAT in praxis. It is connected with the theoretical issues presented in the lectures and the importance is placed on the connection of science education with the early grade pupils' surrounding environment.

The majority of pupils grow in an environment where most appliances are based on electricity. The fact that they turn on/off the lights or the television, place batteries in their toys, learn about the dangers of putting items in the sockets and receive information about how electricity is produced provides a foundation for developing scientific concepts. At the beginning of the lab lesson a discussion takes place about pupils' spontaneous thoughts and ideas about electricity and how these could be used in order to design classroom activities. Then university students try to analyze the activities according to Engeström's triangle and define the intermediary tools, the group work, the rules and the objects which are usually transformed into outcomes in order to create new knowledge in the context of rules that the entire community sets and follows. The unit of analysis is the activity. This makes moving from one activity to another flexible, getting advantage of prior knowledge.

The methodology of this laboratory lesson is based on the expansive cycle of Engeström (Figure 1), which satisfactorily interprets the strategic learning actions and corresponding contradictions, in expansive learning. Expansive learning is part of activity theory and can be considered as a kind of design methodology (developmental research) that aims at change. The series of learning activities in an expansive cycle, which are used in this laboratory lesson, are: (Engeström 1999, p. 383)

<Figure 1about here>

*Questioning*: Criticism or rejection of some aspects of accepted practice and existing knowledge. University students discuss about the development of classroom activities concerning electricity.

*Analysing the situation*: The analysis includes the symbolic and practical transformation of the state to discover the causes or illustrative mechanisms. The analysis relies on questions like "why" (explanatory). One type of analysis is "historical-genetic" and seeks to explain the situation in view of the origin and evolution. Another type of analysis is "real-empirical" seeks to explain the situation to build a picture of internal relations. University students analyze what kind of activities is suitable for the early grade pupils.

*Modeling:* Formation of newly explanatory relationship in a receptive and easily understandable model. This means an explicit, simplified model of the new idea that explains and offers a solution to the problematic situation. University students develop the activities (construction of an electric circuit).

*Examining the new model:* implementation, operation and experimentation with this model so that the potentials, capabilities and limitations can be brought out. University students practice on the activities in the laboratory.

*Implementing the model:* implementation of the model, practical applications, enrichment and conceptual extensions so that the model can be put to practice. University students apply the activities in the school classroom.

*Reflecting and evaluating*: process evaluation and final acceptance in a new, stable form of practice. University students reflect and evaluate on the activities they had designed during and after the practical application.

The analysis of the activity theory and the development of the expansive learning by Engeström offer a new methodology to organized learning in laboratory lessons towards the development and organization of new teaching practices. Within this theoretical framework, the context of natural sciences is associated with the implementation of new didactic strategies and evaluation processes which bring forward innovative aspects of science and a new mentality about teaching natural concepts.

*5.2 LLMAT Lab Lesson*

**A Laboratory Lesson of Magnetism based on Activity Theory**

The LLMAT lab lesson (Laboratory Lesson of Magnetism based on Activity Theory) is an experimental course in the Department of Early-Childhood Education in the field of science education. It was used as a methodological tool to train university students to teach the magnetism issue in the classroom. The central point of LLMAT was the position about the educational success or failure which had been explicated as a collective activity in the social framework. The organization of LLMAT included the following steps:

*Awareness:* co-decision that the topic of magnetism was the most interest topic for our studies at that moment.

*Comparison:* of the laboratory lesson of magnetism with the previous laboratory lessons and use of obtained knowledge, skills and materials.

*Exploration/Activating Prior Learning:* tracing university students' obstacles on their conceptualization of magnetism.

*Creation:* Development of additional insights about magnetism and creation of activities based on the university students' needs.

University students use their prior knowledge on this issue so as to categorize certain materials by testing their behavior when they come close to a magnet. Then, they obtain further knowledge about magnetic properties and create new activities based on their prior knowledge. Furthermore, they take into account pupils' cognitive obstacles while organizing the new activities. This experimental course is designed to bridge the gap between science education and social sciences education and helps to promote public understanding of science, to develop values through science and achieve scientific literacy.

The theoretical and methodological framework of analysis and design activities in this lab lesson is the development approach to research Yrjö Engeström (2005). Before the introduction of CHAT in the laboratory lessons, the students in most cases were usually treated as passive recipients of information, whereas the teachers took on the role of an information dispenser, authoritative expert and fountainhead of information and knowledge. The key elements of our method include the eight-step model of Mwanga (Mwanza, & Engeström, 2003).

Students participated actively in the designing of lab activities and followed the eight- step model of Mwanza 2001(Mwanza, 2001).

*Activity of interest:* In this stage university students modified the sort of activity in which they were interested in. The study of magnets began with an exploration of magnetic and non-magnetic properties of certain materials. We provided each pair of students with a horseshoe magnet and encouraged them to go on a "magnetic hunt" with their partner. They explored the room, predicting the behavior of different materials when they came close to a magnet.

*Objective of activity:* University students provided the reason the activity took place. They shared their findings and made observations while experimenting with the magnets.

*Subject in this activity:* They discussed about who were involved in activity (students, teachers, parents).

*Tools mediating activity:* Books and other materials were the tools by which the subjects (university students) carried out the activity. At this point, university students demonstrated a deeper understanding of magnets and magnetic properties, knowledge of the earth's magnetic field, the way a compass works and the usage of magnets in everyday life.

*Rules and regulations mediating the activity:* University students collectively accepted the rules that all had to follow during the activity: a) Each pair of them worked together to explore the strength of the magnet. b) They recorded their findings in their datasheet. c) When university students completed their experimentation, they discussed their findings in the classroom. d) Teacher evaluated the students' responses.

*Division of labor mediating the activity:* The teacher: 1) demonstrated how to set up the experiment (without actually demonstrating the results; this is for the university students to discover), 2) brought the class together for discussion (What happened? Were our hypotheses correct? What conclusions can we make? Which poles repel or attract?). University students: 1) worked in pairs 2) experimented with a partner to determine the magnetic and the non magnetic properties of materials.

*Community in which activity is conducted:* In this step we defined the environment in which the activity was going to be carried out. More specifically, the environment was the class with Greek pupils.

*Outcomes:* This is the final step in which we provided an estimation of the results from carrying out this activity.

*5.3 LLSAT Lab Lesson*

**A Laboratory Lesson of Sound based on Activity Theory**

The LLSAT lab lesson (Laboratory Lesson of Sound based on Activity Theory) follows the methodology of the LLMAT LESSON presented above and it was used as a methodological tool to train university students to teach the sound issue in the classroom. The central point of LLMAT was the position about the educational success or failure which had been explicated as a collective activity in the social framework. The organization of LLMAT included the following steps:

*Awareness:* co-decision that the topic of sound was the most interest topic for the two-week practical application in the school classrooms.

*Comparison:* of the laboratory lesson of sound with the previous laboratory lessons and use of obtained knowledge, skills and materials.

*Exploration/Activating Prior Learning:* tracing early grades pupils' obstacles on their conceptualization of sound.

*Creation:* Development of additional insights about sound and creation of activities based on the university students' needs. University students created classroom material about sound and adapted it to the socio-cultural background of their school classrooms. University students participated in the designing of the activities as well as in the evaluation procedure following the eight step model of Mwanza (Mwanza, 2001).

*Activity of interest:* In this stage university students modified the sort of activity in which they were interested in and started to organize the LLSAT lab lesson. They decided that the production of sound using a variety of materials as well as their body was the activity that interested them most at that point.

*Objective of activity:* University students set the aims that they were going to achieve through this activity.

*Subject in this activity:* They discussed about who was going to be involved in the activity (students, teachers, early grade pupils, parents).

*Tools mediating activity:* Books and other materials were the tools by which the subjects (university students) carried out the activity. At this point, university students demonstrated a deeper understanding of sound concepts and connected them with everyday life situations.

*Rules and regulations mediating the activity:* They collectively accepted the rules that all had to follow during the activity: a) Each pair of the university students worked together to define the kind of sound each material made. b) They recorded their findings in their datasheet. c) When university students completed their experimentation, they discussed their findings in the classroom. d) Teacher evaluated the students' responses.

*Division of labor mediating the activity:* The teacher: 1) demonstrated how to set up the experiments (without actually demonstrating the results; this is for the university students to discover), 2) brought the class together for discussion (What happened? Were our hypotheses correct? What conclusions can we make? How can we produce sound?

University students: 1) worked in pairs 2) experimented with a partner to determine what kind of sound each material produces.

*Community in which activity is conducted:* In this step we defined the environment in which the activity was going to be carried out. More specifically, the environment was the class with Greek pupils.

*Outcomes:* This is the final step in which we provided an estimation of the results from carrying out this activity.

*5.4 Cartoons as a Tool towards Scientific Literacy*

This laboratory lesson introduces the natural concepts of floating and sinking by the use of interdisciplinary means such as comics and cartoons-animations. Its main objectives are achieving scientific literacy and understanding of Nature of Science NOS from the early grades. Furthermore, it leads to rethinking scientific literacy (Roth & Lee, 2004), in the sense that it develops new methodological tools that could reform science education. From the NOS principles (Mc Comas 1998, 2005) the importance has been stressed on the following 5 principles:

2) Knowledge production in science shares factors, habits of mind, norms, logical thinking and methods.

5) Science has a creative component.

6) Science has a subjective element.

7) There are historical, cultural and social influences on the practice and direction of science.

9) Science and its methods cannot answer all questions.

These principles are a powerful methodological tool in order to design natural science activities in the early grades. This study presents an application of NOS in classroom in which certain abilities are practiced concerning floating and sinking concepts.

University students participated in the lab lesson and practiced during the following sections:

1. Narration of the adventures of Sponge Bob Square Pants (in http://www.spongebob.games.biz), a popular cartoon who lives in a city under the sea who faces unexpected problems of floating and sinking.
2. Predictions of which items float or sink.
3. Testing of predictions.
4. Providing reasonable causes for floating or sinking.
5. Overcoming cognitive obstacles.
6. Identifying skills of scientific method.
7. Designing classroom activities.
8. Connecting didactic strategies with NOS.

The didactical scenario was designed following certain techniques of drama in education in combination with science education techniques. University students had to adopt this scenario in order to teach floating and sinking concepts in pre-primary school classrooms. As students moved on from one stage to the other they exchanged roles in order to find the solution of problem concerning floating and sinking concepts. They defined the place and time and through role-playing, argumentation, conduct of experiments, evaluation they reached the conclusion.

*1. The letter.* University students receive a two-page letter from Bob Sponge. The letter describes everyday life in Bikini Bottom which was normal until the day the wicked witch Lavinia the Maze changed the rhyme of Bob Sponge Squarepants' song as well as the substance of water. As a result, certain parts of the city started to float while others sank and Bikini Bottom was led to destruction. It is in Bob's hands to save the city so he asks for help. Looking in his great-grandmother's books he found a plan. He has to find out which items float and which ones sink in water and build a model-city using these materials.

The letter is accompanied by photos of Bikini Bottom and of Bob and his friends, a sticker album and a magazine in which students can see the adventures of Bob Sponge.

*2. Teacher in role.* Teacher in Bob Sponge role discusses the problem with students and provides information about the city and the situation described in the letter. University students ask questions and try to find a way to help Bob save his city.

*3. Painting.* University students draw the city of Bikini Bottom in a big piece of paper.

*4. Argumentation.* University students are divided in two groups, the floating group and the sinking group. Each group

has to discuss about the behavior of certain materials when put in water and present argumentation of why some of them sink and others float. A representative of each group announces estimations and provides reasons.They make predictions about the behavior of each material in water and then, they fill in the following board of predictions.

*5. Prediction board. Material:* stone, nail, button, potato, orange….*Sinks:* YES ….NO….*Floats:* YES NO

*6. Experiment.* University students put the different materials one by one inside the water and observe what happens. They classify the materials in two categories according to their behavior inside the water. Finally they test their predictions, and discuss about the cognitive obstacles, the skills of scientific method used and they provide ideas for extra activities.

*7. Telephone conversation.* University students listen to one part of a telephone conversation. The teacher in the role of Bob receives a telephone call from Patrick, his best friend in Bikini Bottom. Bob writes down four key phrases that he hears from Patrick and tries to find out with the aid of University students what they mean. Each phrase leads to an experiment which is performed in class.

*Phrase 1:* A whole peanut or half of it floats or sinks you will see!

*Phrase 2:* Put peanuts in carbon dioxide, they will perform amazing tricks by your side!

*Phrase 3:* Cut the potato, cut the potato!

*Phrase 4:* Step in a boat of soft clay and travel away through the ocean.

*8. Evaluation.* University students draw in a sheet of paper divided in two horizontal parts the items that float on top and those that sink at the bottom.

*9. Game.* University students find a way to make their racing boats move in water without touching them.

*10. Frozen Pictures.* University students present scenes of Bikini Bottom city using their body.

*11. Discussion in circle.* Teacher in role discusses with university students about the knowledge they have obtained so far as well as the prospects of saving the city of Bikini Bottom.

University students had an active role in designing the activities in the lab lesson. This way they became able to adopt suitable didactic strategies in order to teach floating and sinking concepts in pre-primary school classrooms. As they moved on from one stage to the other they exchanged roles in order to find the solution of problems concerning floating and sinking concepts. They defined the place and time and through role-playing, argumentation, conduct of experiments, evaluation they reached the conclusion. As a result of this collective activity university students became engaged in designing natural sciences activities in a socio-cultural environment and studied the interactions in the pre-primary school classrooms of Ioannina.

*5.5 Color Visions from the Past in Science Teaching*

**Connection of History of Science with Science teaching from the early grades**

This study proposes a combination of Natural Sciences and History in the classroom and tends to familiarize learners with certain episodes in the history of science and through this offer different ways of explaining nature. On the one hand, there is science through the scientific method such as observations, experiments and theories and on the other hand there are approaches used in art and literature. In this sense, learning becomes an ongoing process affected by societal and historical conditions in which the interactions of science, culture and society play a central role. This Laboratory lesson included:

-Narration of a story about the adventures of two children who under peculiar circumstances find themselves outside Newton's laboratory and overhear his presentation of color theory to the scientific society.

-Underline the parts of the narration that offer ideas or materials in order to design natural sciences activities about colors.

-Making comics of the main points of the previous narration.

-Description of Newton's drawing about colors.

-Exploring about the names of colors on Newton's disc.

-Predictions on the creation of colors and the way they are connected with light.

-Testing of predictions.

-Research and argumentation on the contribution of Newton to colors theory.

-Providing justifications.

-Overcoming cognitive obstacles.

-Identifying skills of scientific method.

-Designing classroom activities by using the societal and cultural context of past science.

-Connecting didactic strategies with NOS.

A variety of didactic strategies was used which included educational drama, pantomime, cartoons, games, etc. all of which followed the basic principles of CHAT. As a result of this collective activity university students became engaged in designing natural sciences activities and incorporated the history of science in them within a socio-cultural environment. The teaching plan for the university students was to use the basic principles of CHAT in order to have an active role in designing natural sciences activities in the laboratory lessons using elements from the history of science. This way they became able to adopt suitable didactic strategies for introducing the content knowledge in a pre-primary classroom and applying didactic transformations. The classroom activities effectuated in the pre-primary school classrooms included:

- Listening to the narration about the history of colors and discuss.

- Making drawings connected to the narration and compare them with the comics that university students have made.

- Decide on which part of the classroom they will transform to a laboratory.

- Collect the materials they need to conduct the color experiments.

- Recognition of colors around us.

- How things can change their color.

- Shades of colors.

- Analysis of colors with prisms.

- Construction of Newton's disc of colors.

- Making a model of a rainbow.

- Discussion.

During the laboratory lessons university students worked in pairs at the beginning; they read the story about colors and made connections of parts of the story and science education. They discussed about the use of history in science education and about the influence it would have in a school classroom. Each pair exchanged views with others and they all decided to look for more information on this matter. They suggested that they should make a simpler version of the story in order to use it in the school classroom. Finally they decided to work in fours in order to make drawings of basic parts of the story. The role of the laboratory assistant was that of a facilitator during the whole process. Moreover he observed and recorded the interactions between pairs that worked together as well as the interactions of pairs with the whole group.

University students provided views which showed that they had attended a series of Science- Technology- Society lessons and workshops during their studies so far. Moreover, they commented on the social aspect of science and scientists and on connection science and society. Thus, we can see that science is put in a socio-cultural surrounding; in general, it is seen as a discovery of new things in the world we all as a community live. The connection of science with history of science and arts reveal another strong bond between science and society.

**6. Data Analysis**

Research data are collected before, during and after the classroom implementation by observations, video recordings, interviews and analyses. Thus, results come out with the contribution of several groups. This part involves university teachers, lab assistants, university students, early childhood teachers, early grade pupils who work as a community towards reforming of natural sciences education. In the university laboratory lessons, the units of analysis are the activity systems and the different levels of interaction within and between them. All the activity systems involve multiple participants (university teachers, lab assistants, students, external collaborators etc.) who work to achieve common objectives, considering scientific knowledge as cultural, historical and social process and using meditative and analysing tools. Furthermore, internal and external contradictions within and between the activity systems are analyzed as well as change of interactions between mediations which affect all the activity systems in multiple ways.

The Activity Systems (A. S.) presented in figures 2 and 3 are on continuous interactions with one another with the aim

of achieving scientific knowledge. In this regard, the participants, the institutions, the methods, the tools, the objects of all activity systems are connected in a cultural, historical and social process. University students work collectively in the university laboratory (A. S. 1) in order to develop innovative science material and enhance their understanding of the Nature of Science (NOS). Thus, they combine prior knowledge with the present and use prior experience while moving from one activity system to the other. Furthermore, they use the new experience gained and put the outcomes into practice in the school classroom (A. S. 2) towards pupils' meaningful learning and literacy development.

<Figures 2 & 3about here>

Early-grade pupils (A. S. 2) come to understand the scientific concepts not as an individual, isolated phenomenon but as part of the cultural-historical and social background. Furthermore, they realize that scientific concepts can be developed in different institutional settings of the present and the past, as a result of collaborative action, critical thinking, problem solving and argumentation. In this sense, internal activities, such as pupils' understanding of the scientific concepts are shaped with external activities and they both unify to form knowledge structures.

During the laboratory lessons university students have the opportunity to use a variety of meditative and analyzing tools, which can be artefacts or conceptual tools. These include learning theories with emphasis on Cultural Historical Activity Theory, pure science teaching materials and resources, everyday life materials, teaching strategies including a multiple pedagogical outlook on the scientific topic they deal with. Furthermore, they use a large number of ICT tools, such as animations, software, video seminars, laboratory equipment, languages, lectures, and interactive research material from external collaborators.

By using all these tools to interact in the lab lessons as well as in the school classroom, university students developed high level mental functions and became more confident in designing classroom material as well as discussing about scientific issues. As a result, at the end of the academic semester, in June 2011, university students were able to participate in an Erasmus Intensive Programme with the topic of Light and Sustainability. There they worked and exchanged fruitful ideas with students from seven different countries. They attended lectures and seminars connected with the topic of Light and Sustainability, they participated in seven workshops which were organized by the participant countries and finally they collaborated on designing a science curriculum which had to be applicable to all seven countries in their compulsory courses of science education. During the whole procedure, university students were engaged in different levels of scientific activity, acted collectively within the different learning communities and were gradually transformed to professionals working as a collective unit. Moreover, they used their knowledge and experience gained from the laboratory lessons to co-organize with the lab assistants a workshop on the topic of light and colors focusing on the controversial theories of Newton and Hooke.

Data analysis of the school classroom applications has shown that university teachers' training is connected to society as it improves life skills of their pupils under the prism of the modern socio-cultural theories. University students help their pupils develop critical thinking, problem solving and argumentation skills and how to combine their personal experience and knowledge with the interactions of the group. This way, they enhance their professional experience and skills as early grade teachers.

The use of a variety of tools serves the purpose of drawing attention to issues that could be analyzed according to the CHAT theory principles. For example, we could define the tools are used by subjects to communicate with one another in order to exchange experience within the activity or the way the subjects organize the division of labour between themselves and to what extent this is affected by the decisions of the community.

In the LLMAT and the LLSAT lab lessons the results refer to subject-object orientation and especially focus on object. Furthermore, the various factors of the Engeström's triangle - e.g. rules, community, and division of labor – had been studied through analyzing each sub-triangle in relation to the major one (Figures 4-9).

<Figures 4-9 about here>

Activities analysis using CHAT

<Table 1 about here>

The interactions within the learning communities in different institutions are analyzed in the laboratory lessons connected with cartoons and history of science. CHAT theory helped university teachers to design classroom activities in which the goals were not necessarily connected to the pupils' previous knowledge but to the interactions and conflictions that take place in a school classroom. Thus, the implementation of the didactical scenario directed attention to the use of tools, the division of labour, the role of the teacher, and the interactions within the community. In this way a much deeper understanding of the context of natural sciences was established that was associated with the implementation of

new didactic strategies and evaluation processes which have brought forward innovative aspects of science.

CHAT Interpretation of several episodes of the practical application

<Table 2 about here>

This interpretation was inspired by the analysis of Marianne Hedegaard and Marilyn Fleer (2008) about children's development in every day practices. This study presents a modification which combines the child's perspective with the epistemology of Natural Sciences in early childhood.

**7. Conclusions-Implications**

Initial results of using cultural-historical activity theory (CHAT) in natural sciences education laboratory lessons seem promising. The five years research in the field of cultural studies of natural sciences education is a new potential to make natural sciences education a matter for children as future citizens, of a multicultural environment. Collaboration with the university students at the laboratory lessons as well in different societal educational settings with the aid of cultural tools has shown that adopting teaching strategies under the prism of CHAT bridges the gap between theory and praxis in natural sciences education.

At this point, we feel that the key elements of CHAT, activity, activity system, tools, rules, community, division of labor, object, and outcome are all directly applicable to natural sciences education teachers' training for the early grades. A CHAT approach to natural sciences education research could provide a sound basis for the elaboration of educational material based on the learners' needs and interests. Furthermore, it could lead to discover the organizational and other contradictions that affect the learning communities and use them to aid the design and analysis of research investigations. CHAT offers a conceptual framework within which research can be conducted in a large scale by using several methods of data collection as well as a terminology that can be shared by researchers of natural sciences education.

The theoretical framework of analysis of Engeström seems to be appropriate and fruitful for natural sciences education researchers. The Mwanza eight- step model provides natural sciences education learners with skills in order to design innovative natural sciences activities. The cultural- historical approach of Marilyn Fleer and Marianne Hedegaard is a useful guide for university students as it provides all the information about children's development in a socio-cultural environment. Finally, Michael Cole and the Distributed Literacy Consortium have provided, in the project 5$^{th}$ Dimension, an example of an educational activity system in which university students can see multiple interactions of subjects, objectives, tools, rules, division of labour etc. taking place in different educational settings. All those interactions of different methodological processes could offer criteria to analyze and evaluate learning in university natural sciences education laboratories.

Natural sciences teachers' training should have a strong cultural, historical, social, ecological orientation and focus on the interactions and contradictions that take place in the different learning environments. University teachers should become aware that the formation of scientific knowledge in a school classroom is not reached individually, but as a result of the work of a social community in which they belong. As Hedegaard (2008) stresses while describing the role of teacher 'it's not like , you will learn, this is what I'm teaching you, but doing something together, looking something up together, adding some information, that's a really important part of the process'(p.79). Such consideration of the role of the teacher provides pupils a strong knowledge base that will become the foundation for meaningful learning and scientific literacy achievement. Furthermore, it helps to create 'a context for learning not only (about) science but learning for life' (Roth, 2010). As a consequence, work in a university laboratory or school classroom will contribute not only to the collective good of the learners but also to society.

All in all, CHAT seems to be a promising field for introducing the content scientific knowledge, so as to invest on the socio-cultural background of the prospective teacher that will learn, teach natural sciences and also make decisions about scientific and technological matters. Implications and recommendations for further research concerning the use of CHAT in natural sciences education teachers' training are considered of high priority by the ATFISE research group. For example, an in-depth analysis of the role of contradictions that appear within the learning communities could offer progress of understanding and push forward the boundaries of scientific literacy in the field of natural sciences education. This will lead to a holistic understanding of the world by means of education, science, culture and communication.

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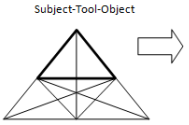
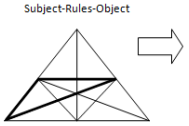
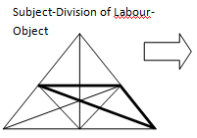
Table 1. Activities analysis using CHAT

| Exploring about magnets as well as magnetic and non magnetic materials. | Activity analysis using CHAT |
|---|---|
| Prospective teacher provides pupils with tools (magnets, materials) and encourages them to experiment freely with the materials. Each pupil chooses the materials which will be used in the activity. Pupils work in pairs, if they want and cooperate with the prospective teacher. | The interaction between the prospective teacher and the pupils helps the mediation of the subject-object-tool system. The interaction that occurs among pupils is very important. As the following triangle shows, the interactive system subject-object-tool, allows both the pupils and the prospective teacher to work towards a common goal- object.   |
| Pupils are experimenting freely with the tools (magnets, magnetic materials, non- magnetic materials). The prospective teacher encourages them to:<br>1.Use one magnet each time<br>2.Use one chosen material each time<br>3. Bring the material close to the magnet so as to observe if the magnet can attract it or repel it.<br>4. Put the material that a magnet can attract in a class-group.<br>5. Put the material that a magnet cannot attract in another class-group. | The interactive system helps to activate and involve pupils-subject in the activity, and to create rules within the group. The interaction within the subject-object-rules system is presented in the following triangle. The rules, as well as the tools help to reach the object.   |
| The prospective teacher helps the group of 4 pupils to choose the materials and lets them experiment. Then pupils give instructions to their team members about the way in which they will work (individually, in smaller groups). | In this interactive system: pupils-subjects cooperate during the activity and find ways for sharing responsibilities (division of labor) in each separate group. The group of pupils- subjects is in constant collaboration with the prospective teacher, who is involved in the activity, only if his help is requested from children.   |

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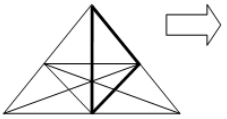
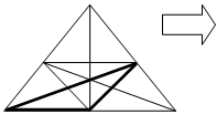
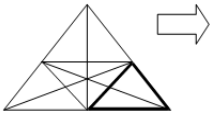
| Production of sounds with different materials | Activity analysis using CHAT |
|---|---|
| The group of pupils during the activity interacts with other groups of children. It is therefore possible to make some questions to the pupils of other groups, to exchange tools, to determine differences between the materials. | The following interactive system consists of: learning community -tool- object, and helps the team to interact and transfer their data and their observations within the other groups. The exchange of tools (verbal, materials) helps children to collaborate, to make different comments, to share their materials and to exchange their aspects about the results of each group.<br>Community-Tool-Object<br>  |
| The groups of pupils decide on the rules that have to be followed during the activity. They decide to:<br>1.Use one material to produce sound each time.<br>2.Produce sound by only one way each time (e. g. by blowing, clapping).<br>3. Make observations on the volume of the sound each time.<br>4. Classify the materials according to the way they make sound.<br>5. Share and exchange tools and materials with the other groups. | The following interactive system: learning community- object- rules helps the development of the activity. The rules that pupils set lead to a better collaboration of each group. Furthermore, the rules ensure the mobility and interaction of the different groups. The different effects - objects in each group, provide different aspects of the outcome of the same activity. This leads to new interactive systems.<br>Community-Rules-Object<br>  |
| The groups of children record their observations and results that obtained from the outcome of the activity.<br>They assume therefore to distribute their responsibilities for each group and to present their results to other groups. The prospective teacher supports pupils to work in groups and he gives details only if it is required from the groups. | The interactive system presented below: learning community- division of labor- object, develops different functions for the members of each group (division of labor). The division of labor is formed in the wider learning community (community). The learning community is formed by both the pupils participating in the activity, and the prospective teacher (subject), which plays a supportive and cooperative role.<br>Community-Division of Labour-Object<br>  |

Table2. CHAT Interpretation of several episodes of the practical application

| Transcription of the science lesson | Interpretation |
|---|---|
| A pupil finds the letter of Bob Sponge on the doorstep of the school. She delivers it to the university student wondering who could have sent it and how. | Pupils connect the fact that they have received a letter with an ordinary activity. Their parents receive letters at home so the letter becomes a tool to motivate pupils to act as a group dealing with a situation. |
| Pupils stand in two rows, the sinking and the floating row. Those from the first row pick up items that sink and provide a reason for this behaviour while those from the second do the same with items that float. If anyone cannot decide he/she stands between the two rows and listens to the arguments of both rows so as to decide about the behaviour of the item. | Pupils use argumentation in order to talk about the behaviour of different items when put in water. They provide reasons for floating and sinking based on the experience of their own socio-cultural background, they use their own epistemology in order to describe the natural phenomena and finally they try to persuade those who have not decided yet about floating and sinking behaviour. Pupils interact as a group so as to decide about the behaviour of the items. University student provides help only if asked. |
| After the experiment Dimitra wanted to make the potato float. She put it inside a hollow plastic toy and said: 'see? I have made a lifejacket for the potato, so it can swim!' | Pupils describe scientific concepts and modify them in a creative way. |
| Pupils organise experiments about light and colors and try to follow the way Newton presented his discoveries to the scientific society. The role of university students is that of a mediator and a facilitator. | Pupils become familiar with some episodes in the history of science and use elements from these to organise their own scientific work and progress. |
| University student asks pupils where they can find light and refer to a variety of light sources such as the sun, candles, torches beams of light and even fireflies. | Pupils participate in a problem solving situation and interact with other pupils and university students in order to reach the desired outcome, to learn about light and its properties. |
| Pupils provide reasons for the creation of colors and connect them with rainbows combining their personal experience with the prism experiments. | Pupils describe scientific concepts providing examples of their logical thinking and their everyday life. |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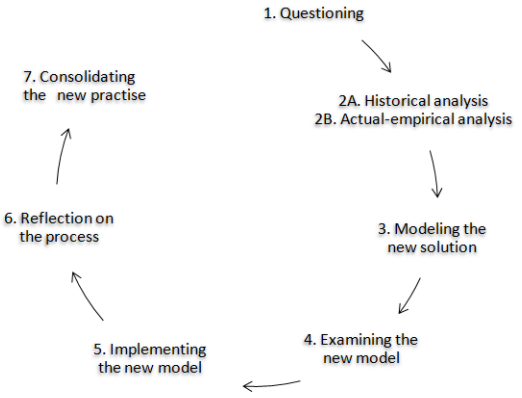
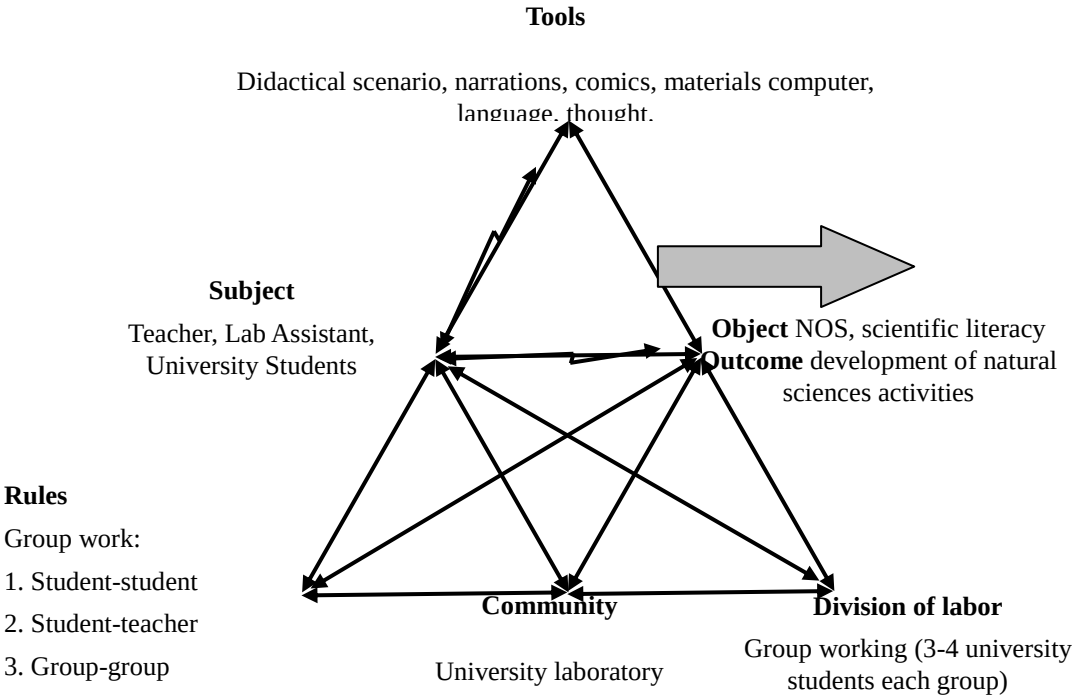



Figure 1. The cycle of expansive learning (Engeström, 1999)




ACTIVITY SYSTEM 1 (in a university laboratory)

Figure 2. The Activity System Model (Engeström, 1987)

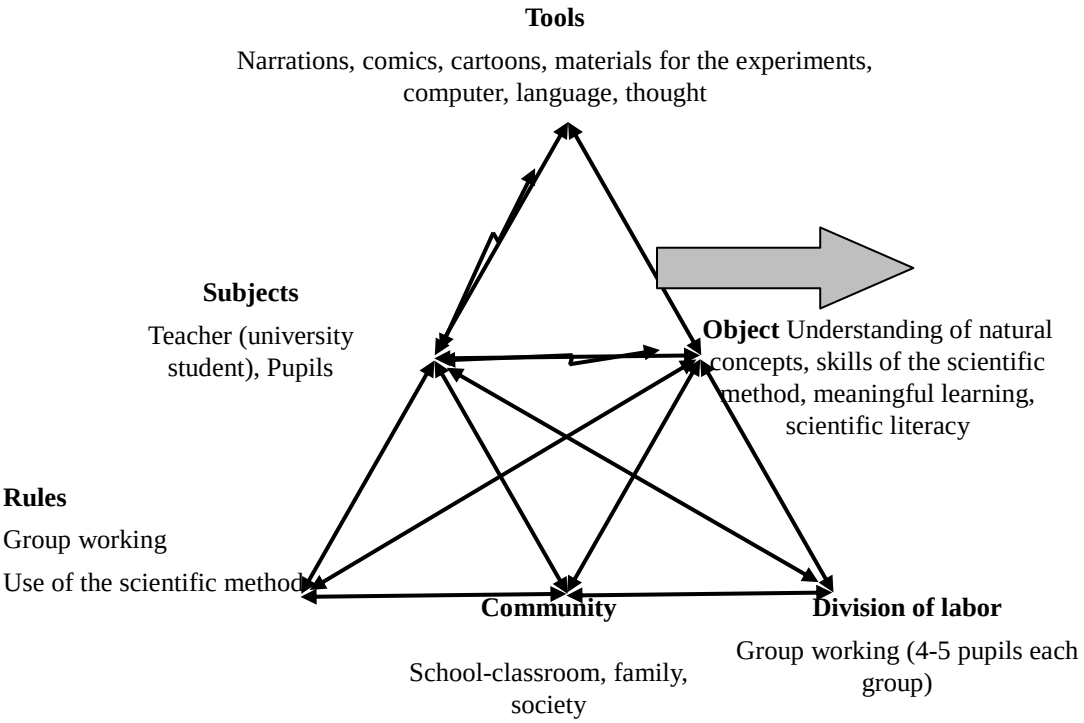
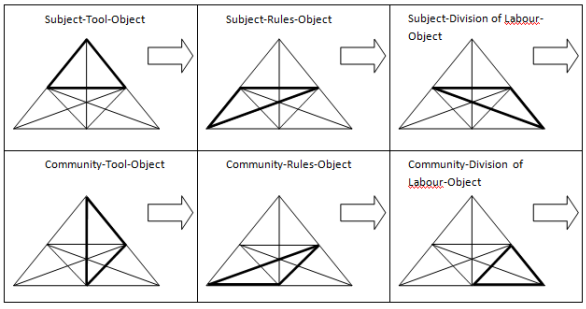



Figure 3. The Activity System Model (Engeström, 1987)




Each sub-triangle shows the interaction of 3 factors which produces some different outcomes.

Figures 4-9. (Based on Engeström's triangle, 1987)