Color Visions from the Past in Science Teaching Within a Cultural Historical Activity Theory (CHAT) Context

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Abstract

This study uses history of science in teaching natural sciences from the early grades. The theoretical framework used is Cultural Historical Activity Theory (CHAT), which is a theory with expanding applications in different fields of science. The didactical scenario, in which history of science is used in a CHAT context, refers to Newton's presentation of color theory to the scientific society. The question addressed in this study is to connect the history of science with science teaching from the early grades and propose the socio-cultural aspect of teaching natural sciences as a means to reform natural sciences education. The study is divided in two parts. The first part concerns a series of natural science activities and the proper didactic strategies to teach colour theory concepts practiced in the university laboratory by prospective teachers. The second part is an application of the previous activities in Ioannina pre-primary school classrooms. Research data are collected before, during and after the classroom implementation by observations, video recordings, interviews and analyses. The initial results of incorporating history of science material in natural sciences within the CHAT context seem promising. Using elements from the history of science proved a useful tool in order to design science education activities. During the practical application of the activities, pupils realized that construction of scientific concepts is a collective procedure within the evolution of human culture. They found out that the alternative ideas they have about natural concepts and phenomena were also expressed by famous scientists. By using basic principles of CHAT in classroom situations we contribute to the establishment of science education as participation in the community, as well as a new ontology and epistemology in teaching scientific concepts.

Keywords: Cultural Historical Activity Theory, History of Science, Natural Sciences, early grades.

1. Introduction- Theoretical Framework

This study uses history of science in teaching natural sciences from the early grades towards scientific literacy which has become a priority for educational experts and institutions in many European countries and worldwide. It is part of a research project which is connected with Cultural Historical Activity Theory in Formal and Informal Science Education (ATFISE project). The main objective of this project is to contribute to an emergent agenda about Cultural Historical Activity Theory (CHAT) and science education in Europe from the early grades. Making an early start establishes the foundations of scientific knowledge that forms individualities who consider science as a lifelong learning activity. In this sense, science education is established as participation in the community (Roth & Lee, 2004) with connections to the society in its cultural and historical evolution. This could reform science education from its inside in a physical and logical way, while the community as well as the individuals learn about science and its history.

Researchers and science educators have provided argumentation for the implementation of history of science in science teaching (Matthews, 1994, Seroglou & Koumaras, 2001) for a long time. An appropriate science teaching curriculum at

all educational levels which helps understanding natural concepts and develops scientific argumentation should integrate elements from the history of science (Matthews, 1994). Great importance is placed on the child's education from the beginning of his life at an international level. The fact that infants try to explore their surrounding environment by using their senses and try to satisfy their natural curiosity provides a foundation for developing scientific concepts. 'Science education is too important to be left alone to older children and students for it might be too late for creating the foundations of knowing that lead to personalities interested in science as a long endeavour' (Roth, 2011, p. 21). At an early stage learning in Natural Sciences is a result of social interactions connected with exploring in authentic environments, practicing skills of observation, classification, communication e. t. c. and making sense of the world around us. Reforming of the Greek national curriculum for the early grades both in 2003 and in 2011 has put science education on a cultural- historical foundation. The content of science education in the early grades concerns topics and concepts from the surrounding environment during its historical evolution: human life, social structures and relations, life of plants and animals, places and people, natural phenomena. 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.

History of science plays an important role as it studies and presents the scientific concepts with different interpretations through different periods of time. In this regard, it becomes a useful tool towards understanding that scientific knowledge can be a historical knowledge (Bevilacqua& Bordoni 1998). A series of scientific concepts or phenomena can be described by theories supported by different scientists at different periods of time. This means that scientific knowledge is not static; it is a result of interactions among elements that change through time: theories, principles, tools, devices, technological advancement e. t. c. As a result, the same scientific phenomenon is interpreted in various ways and affects creation of scientific knowledge. Within the learning procedure, 'the history of physics is inside physics; they cannot be divided and considered as 'optional subjects', (Bevilacqua & Bordoni 1998, p. 451).

This study is part of a wider collaborative action research project which takes place in the University of Ioannina and aims to establish a collaborative network of professors, PhD students, university students and school-teachers. The efforts are concentrated on improving the methods that scientific concepts are taught in the early grades and on introducing new teaching and learning strategies in science education. Furthermore, the support of learning communities and the development of key competences and life skills in science education are also key elements in the research project.

The theoretical framework is based on Cultural Historical Activity Theory (CHAT), which is a theory with expanding applications in different fields of science. The didactical scenario, in which history of science is used in a CHAT context, refers to Newton's presentation of color theory to the scientific society. The students' working in groups, the use of intermediary tools and the objects which are usually transformed into outcomes play an important role for creating 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. Thus, learning about scientific concepts becomes meaningful for the students' community who interact with one another as well as with meditative and analysing tools and means within the activity's context (Engeström, 1999) and within their cultural-historical background. In this sense, science education is not only focused on the scientific content but also on presenting science as a human activity (Nielsen and Thomsen, 1990) with social applications. On the grounds that this study stresses the importance on the socio- cultural and historical aspect of teaching natural sciences in the early grades, the following research questions are addressed:

1. Is it possible to connect the History of Science with Science Teaching from the Early Grades stressing the importance on the socio-cultural aspect of teaching Natural Sciences?
2. Is it possible to connect the History of Science in the case of color theory with Science Teaching from the Early Grades?
3. Is CHAT a coherent theoretical framework that can provide motivation to incorporate elements of the colour theory in Natural Sciences Activities from the Early Grades?

2. Rationale

The rationale for this study was based on the observation that both teachers and prospective teachers present to be not very well informed about teaching Natural Sciences in the early grades. According to Roth and Tobin (2002), both prospective and in-service teachers found teacher training in the university was not preparing them adequately for their actual classroom teaching, indicating that there is a need to bridge the gap between theory and practice within the frame of teacher education. The question addressed in this study is to connect the history of science with science teaching from the early grades and propose the socio-cultural aspect of teaching natural sciences as a means to reform natural sciences

education. In other words, to use CHAT into the context of natural sciences education in order to provide motivation to prospective teachers to develop innovative natural sciences activities incorporating the history of the scientific concept and help them to teach natural concepts in the early grades. Many researches (e. g. Bravo 2005, Lederman 1992, Plakitsi, 2007) on teacher education have reported the fact that teachers have their own ideas about science and Nature of Science. These ideas are on the one hand different from the scientific views and on the other, seem to cause anxiety to teachers. As a result, they need to become familiar with teaching methods that will help them overcome worrying images of sciences and design stimulating classroom activities. History of science can become a powerful cultural tool towards this direction as it involves interactions of science, culture and society, all of which support the professional development of both in-service and prospective teachers.

3. Aims

The aims of this part of the collaborative action research study were set under the perspective of considering scientific knowledge as a dynamic activity system in which the participants, the institutions, the methods, the tools, the objects are connected in a cultural, historical and social process. They are strongly connected with the general purpose of science education in the early grades for meaningful learning and literacy development. Early starters are provided with the opportunity to practice skills of the scientific method and to develop positive attitudes and values towards Natural Sciences. In this sense, the study seeks to:

-Use elements from history of science in a Cultural Historical Activity Theory (CHAT) context in order to design and analyse natural sciences education activities.

-Propose an alternative teaching method on prospective teachers.

-Apply the certain teaching method in order to make prospective teachers capable of transferring it from the university lab to the school classroom.

-Provide opportunity to teachers and prospective teachers to develop innovative science activities for their pupils by using the societal and cultural context of past science.

-Provide opportunity to prospective teachers and pupils to become acquainted with basic researching skills.

4. Methodology

In this part of the collaborative action research project the importance is stressed on the development and the application of a new method of teaching and learning Natural Sciences in the early grades and on connecting learning with real life situations from the present and the past. The collaboration of both prospective and in-service teachers offers a wide field for improvement and incorporation of the new method in the Natural Sciences curriculum for the early grades.

The study is divided in two parts. The first part concerns a series of natural science activities and the proper didactic strategies to teach colour theory concepts practiced in the university laboratory by prospective teachers. 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 cultural- historical approach by Marilyn Fleer and Marianne Hedegaard (2008,2010) about children's development in every day practices and

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

The theoretical framework of analysis of Engeström was used to study the interactions within the different learning settings (university laboratory, school classroom). The cultural- historical approach of Marilyn Fleer and Marianne Hedegaard was a useful guide for university students as it provided all the information about children's development in a socio-cultural environment. Finally, the 5th Dimension project, by Michael Cole and the Distributed Literacy Consortium, was used in order to follow basic elements of 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 offered the opportunity to improve learning in university natural sciences education laboratories.

5. Data Analysis

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.

The Laboratory lesson which was effectuated within the frame of a university lesson entitled 'Didactics of Natural Sciences' included:

-Narration of a story about the adventures of two children (see Appendix 1) 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 (picture 1, see Appendix 2).

-Exploring about the names of colors on Newton's disc (picture 2, see Appendix 2).

-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 second part is an application of the previous activities in pre-primary school classrooms. Five pairs of third-year students were identified from a sample of 150 university students all of which participated in Natural Sciences workshops concerning a variety of scientific concepts. Selection was based on personal interest in history of science education as well as mini-projects and discussions about historical and socio-scientific issues. The students had the opportunity to teach color concepts over the course of two weeks in five different pre-primary school classrooms of Ioannina. 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.

Observation by two external observers was conducted. Video-tape recording of the classroom activities provided material for discussion and evaluation of the teaching process. Finally, a semi-structured interview with the students responsible for each classroom was another source of evidence. Research data were collected before, during and after

the classroom implementation by observations, video recordings, interviews and analyses. This part involved university teachers, lab assistants, students, early childhood teachers, early grade pupils who work as a community towards reforming of natural sciences education.

The didactical scenario was designed in connection with the Greek National Curriculum (2011) which has recently been reformed. The development of communicative skills, collaborative and creative work, problem solving and critical thinking are some of the priorities of the curriculum's planning and development. The planning and development of the context of different subjects such as Language, Mathematics, Studies of the Environment, Drama, Music and Physical Education is not considered as an independent action but all the subjects interact during implementation in the classroom. Moreover, the curriculum supports pupils' learning with skills, attitudes and values which reinforce the cross-thematic perception. Taking this into account, teaching scientific concepts is an interdisciplinary procedure that takes place not only in the school classroom but also in the laboratory and in the environment with strong connections to society. The activities of the laboratory lessons were also connected with the Greek National Curriculum (2011) Great importance has been stressed on discovering the basic characteristics of the properties of different materials of the natural world, on understanding the importance of different skills of the scientific method and finally on describing the natural phenomena using their epistemology. The role of the teacher is that of a mediator and facilitator as he/she observes the interactions of the pupils with the materials and with proper questions discovers the ways pupils understand the natural phenomena and develop their interest for historical events, problems and dilemmas of people at different historical periods.

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.

Suggested activities by the university students that could follow the narration:

- recognizing colors of different items around us
- playing with shadows
- weather conditions (rain, storm, cold, rainbow)
- color shades of grey
- playing with torches
- playing with mirrors and prisms
- talking about waterfalls
- pretending to be scientists and become aware that science can be dangerous
- colors according to emotions (draw a picture of the city in vivid colors and another one in black and white to show change of the citizens' emotions).
- construction of Newton's disc
- card games with colors
- make the portraits of Newton and Hook and look for information about their lives
- make puppets of the basic heroes in the story and play puppet show
- create Uncle Albert's laboratory in order to experiment.

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.

5.1 Laboratory and Classroom Practice

In both the university and the school science classroom 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, early grade pupils etc.) who act towards some common goals, 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. Finally, the role of the incorporation of history of science as a tool in all activity systems is studied.

All the Activity Systems (A. S.) presented 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 study certain theories of colors that were developed in the past, 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 knowledge of the past with the present and use the prior experience of history while moving from one activity system to the other. Furthermore, they use the experience gained from the university laboratory (A. S. 1) and put the outcomes into practice in the school classroom (A. S. 2) towards pupils' meaningful learning and literacy development.

Pupils (A. S. 2) come to understand of natural concept of colors not as an individual, isolated phenomenon but as part of the historical and social background.

Furthermore, they realize that natural 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 the concept of colors are shaped with external activities and they both unify to form knowledge structures. This combination provides early starters the foundation for meaningful learning and literacy development within their cultural, historical and social background.

5.2 Interviews

The interviews were conducted with the university students that implemented this didactical scenario in class in pairs. Questions at this point, (see Appendix 3), referred to their personal involvement in history of science or in a historical experiment as students, the attitude of pupils towards the story as well as towards the whole didactical scenario, evaluation of using historical elements in a classroom and connecting them with Natural Sciences e. t. c .Answering the questions one by one, revealed students' orientation to a more confident way of handling scientific views in class and connecting them with history. They faced some difficulty in connecting the history of colors with the scientific activities in the classroom especially when it came to the contradiction of Newton and Hooke. At this point, they used the contradiction to make pupils realize that there is not only one opinion or theory even in the interpretation of the scientific phenomena. Most of the students insisted on having more practice in new teaching materials about history of science and stressed the importance on the inclusion of appropriate history of science courses in teacher training.

Creating their own comics connected with the history of colors and using them in science activities made them feel that they had a powerful means for keeping pupils' interest vivid during the whole procedure. They also felt familiar with alternative teaching methods which will help them design stimulating classroom activities. Finally they felt more confident about investing in their future profession as they gradually became capable of overcoming their anxiety and dealing successfully with scientific matters in class. CHAT theory helped them to formulate interesting research questions in order to design activities, to set goals 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. Finally, they felt confident to use the knowledge and experience they have gained in order to participate in an Erasmus I. P. workshop and support their view in a debate about Newton's and Hooke's aspects of the creation of colors.

6. Conclusions- Implications

The initial results of incorporating history of science material in natural sciences education laboratory lessons in the cultural-historical activity theory (CHAT) context seem promising. The theoretical framework of analysis of Engeström provides natural sciences education learners with skills in order to analyze natural sciences activities. Furthermore it seems to be an appropriate context to connect History of Science and Science Education as it offers a wide field of

analysis of the interaction of the present and the past activity systems. 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 5th 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. 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. Furthermore, using elements from the history of science proved a useful tool in order to design science education activities.

During the practical application of the activities, pupils realized that scientific concepts were constructed, spread and changed not by an individual but in a collective procedure within the evolution of human culture. They found out that the alternative ideas they have about natural concepts and phenomena were also expressed by famous scientists. In this sense, science becomes part of their history and culture which makes learning meaningful. As a result, they developed communication, cooperation, problem-solving and decision making skills. They worked interactively in groups, used tools in order to deal with the situation presented in the historical context, provided argumentation, exchanged information about life of scientists in the past, all of which contributed to scientific literacy. The use of comics and cartoons seemed to reinforce the learning process. Dealing with scientific concepts with the aid of comics and puppets contributed to better understanding of science, connecting with prior knowledge and building a strong interactive network in order to achieve meaningful learning of the scientific content.

In this regard, teaching natural sciences became a dynamic activity system which involved multiple participants all of which acted towards some common goals, considering scientific knowledge as cultural, historical and social process and using meditative and analyzing tools. By using basic principles of CHAT in classroom situations we contribute to the establishment of science education as participation in the community, as well as a new ontology and epistemology in teaching scientific concepts.

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Table 1. Chat Interpretation of several episodes of the practical application

Transcription Of the Science Lesson	**Interpretation**
University students discuss with pupils about the scientists of the story and their role in the color experiments. Pupils suggest that they should all wear white robes and make cards with their names on so as to become scientists themselves, like doctors.	Pupils express their own ideas about scientists and connect them with an ordinary activity (visiting a doctor). Their images of scientists become a tool to motivate pupils to act as a group dealing with a situation.
Pupils confirm that they have seen scientists in advertisements on TV, on the news and ask for details about their residence, their friends, their birthday and their daily life.	Pupils lead their life in a socially organised community under the influence and protection of their family. Getting to know that despite their hard work scientists have their own personal life makes them believe that learning is a collective activity. Thus, they have to deal with scientific concepts in order to work like the scientists of the story.
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 provides pupils with a variety of materials in a box and encourages them to explore their properties by using their senses.	Pupils explore the materials on their own, with other pupils and ask the university student for more information. Group interactions among university student, pupils and materials (tools) take place during the activity.
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.
Pupils use colored transparent glasses and see that colors are not characteristic of the different items but they change. Finally they discover that when they put on glasses of two colors a new color is produced exactly as when they mix colors while drawing.	Pupils describe scientific concepts using their own epistemology and modify them in a creative way.
Pupils listen to the story about Newton's colors decide to transform a part of the classroom to a laboratory, in which they will experiment on colors.	Pupils organize the experiments in class; they interact within the group and with the University student, set rules and use the materials in order to conduct the experiments.
When it was time to finish the story about Newton's colors pupils asked if there were more scientists that have researched about colors and rainbows. They looked for information about it with the aid of the university students.	Pupils show interest to extend the knowledge they have gained and suggest the use of new tools.
Pupils asked nursery-school teachers to play games about colors and rainbows on the internet.	

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ACTIVITY SYSTEM 1 (IN A UNIVERSITY LABORATORY)

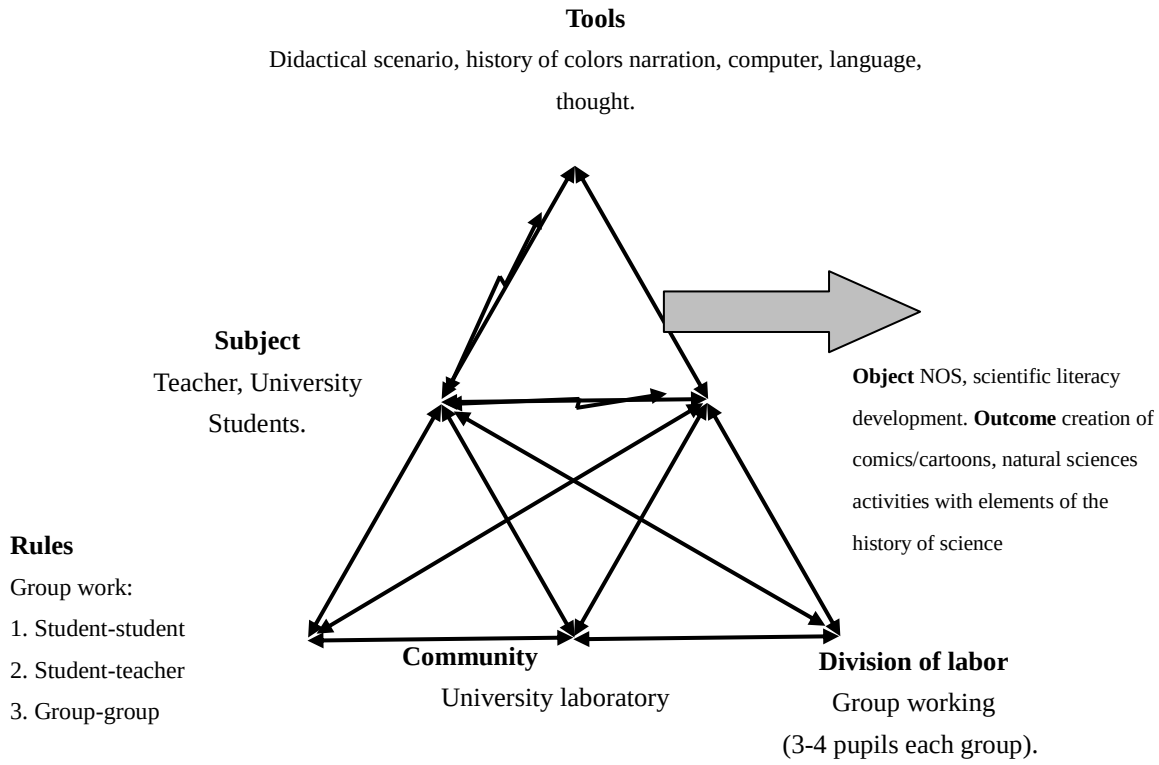


Figure 1. The Activity System Model (Engestr öm, 1987)

ACTIVITY SYSTEM 2(IN A SCHOOL CLASSROOM)

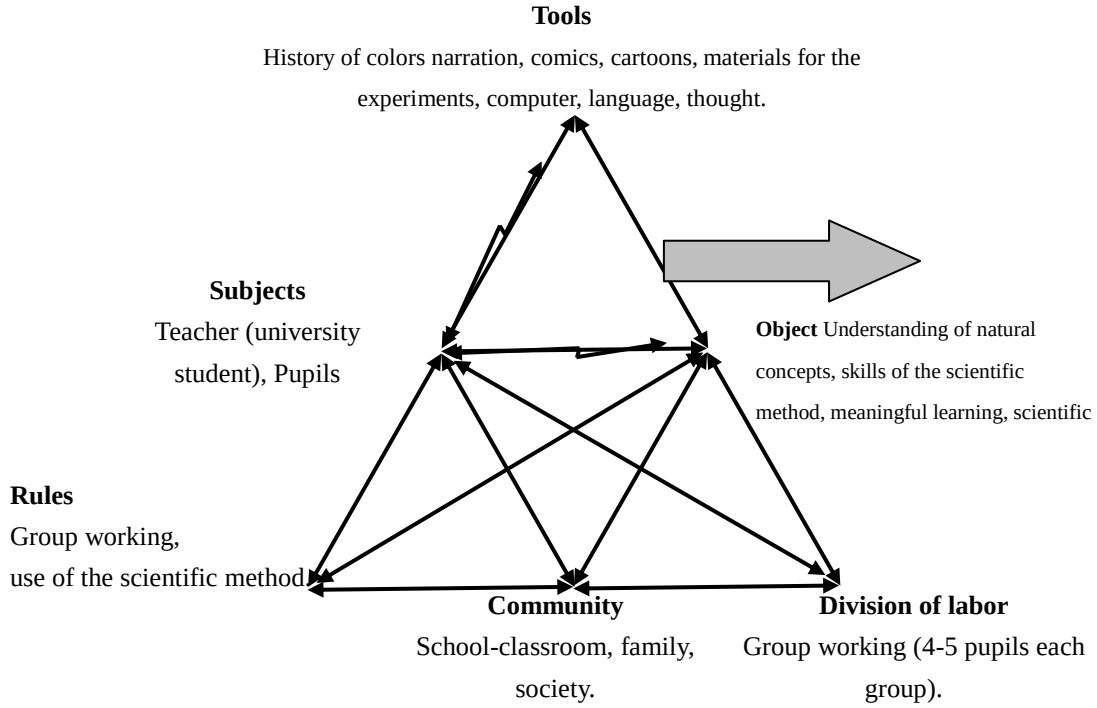


Figure 2. The Activity System Model (Engestr öm, 1987)

Appendix 1: Visions of colors (story)

Phoebus and Iris were completely aware of what was going on in their town during the last three months. The colors around them seemed to fade and everything turned almost black or white day by day. Most people claimed that this was happening because of the torrential rain that had been falling for a long time.

When the sun would come out everything would be in place: all the colors would return, together with the rainbow which would be visible among the tall, grey buildings. Then, they would start exchanging myths about the rainbow and about the pot of gold that was hidden at the edge of the rainbow. Some rumored that the colors of the rainbow were seven elves with strange names that were forced to live and work together and never separate. They were the guards of the treasure and they were visible only when there was a combination of sun and water.

Phoebus and Iris knew deep inside that the colors would slowly disappear as no one in the town paid any attention to the nature around them. That rainy Sunday afternoon, they went to visit uncle Albert who could always change their mood in seconds. Uncle Albert lived with his son Noah in a two storey cottage, full of dimly lit rooms, at the far end of the town. He presented himself as an up-coming scientist and hardly ever went out of the cottage which had been converted to a fully equipped laboratory. Although he spent most of the time working in it he hardly ever talked about the results of his work. When Phoebus and Iris came to his door, he always cheered up as Noah played with his cousins and left him to the peace of his laboratory.

Playing hide and seek inside the dimly lit rooms of the cottage was their favorite game so once again they didn't miss a second on formalities. Stepping on their toes Phoebus and Iris ran to hide in the attic not paying any attention to the sign which prevented any visitors from entering. The door creaked and was almost locked behind them. Inside the attic, everything was quiet. The room had very little furniture; just opposite the door, there was a large wooden wardrobe and on the walls there were portraits of scientists reminding faces of the past. It was too dark to read the signs and find out who they were but the look on their eyes was penetrating. The best hiding place inside the room was the wooden wardrobe so Phoebus and Iris popped into it at once. It was not totally dark inside the wardrobe as beams of light went through the small gaps around it. After some time they realized that their cousin would never find them so they decided to get out and surrender themselves.

All of a sudden they realized that the door was locked and everything started to swirl at an extremely high and uncontrolled speed. In a few seconds, the swirling had stopped and with a sudden bang the door of the wardrobe opened. Phoebus and Iris, hand in hand, shivering with cold and fear jumped out of the wardrobe. They stepped on something that felt like dry leaves, they tried to look down but it was so dark they could not see anything and it was very cold. This place was totally different from their uncle's cottage and from every other place they had seen in their lives. They decided to move on the dry leaves which seemed to be a plain with no end. They walked on cautiously, carrying a million of thoughts in their minds but not uttering a word.

Suddenly, they discerned a light at a short distance and when they moved closer they realized that it was coming from a window pane of a house, standing in the middle of nowhere. The window pane was half-open so they stood on their toes, held their breath and stared inside. The room was pretty dark, with old wooden furniture. A man was standing in the middle of the room and almost in front of a mirror. He had long hair and he wore strange clothes and certainly out of fashion. In fact it seemed that he had jumped out of one of the portraits in the attic of uncle Albert and was now standing opposite them, looking at them with the same penetrating eyes. He had a torch in one hand and seemed to be giving a lecture as Phoebus and Iris overheard:

'Dear Sirs,
I had been provided with a triangular glass- prism, in order to work on the widely known and discussed 'Phenomena of Colours'. Thus, I darkened my chamber, and made a small hole in my window-shuts, to let in a quantity of the sun's light. Then, I placed my prism at the entrance of the beam of light, so that the light could be refracted to the opposite wall. At the beginning, it was a real entertainment to watch the vivid and intense colours produced on the wall; but after a while, I was surprised to see that had an oblong form, which according to the laws of Refraction, I expected to have been circular. "Everyone in the room went silent while waiting to see what would happen next. Phoebus and Iris could clearly hear their heartbeats and felt their bodies shiver in front of a great discovery.

- What are the'Phenomena of Colours'? whispered Phoebus.
- I have no idea, all I know is that colors exist inside things such as flowers, feathers of birds, rainbows, in everything that is colored, answered Iris.
- What is this all about light beams, light and shapes? And why did he have to darken the room in order to see the colors?

- How am I supposed to know Phoebus? I am only 7 years old and I am quite certain that these things are taught in higher levels at school. Besides, if you look very carefully inside the room, you will see that there are no children involved in such conversations and …..

'Put your handth in the air and turn around very-very thlowly!'

Phoebus and Iris were so absorbed in their conversation that they had not heard anyone approaching them. As they were turning exactly as they were told they could hardly see, in the dark, the weirdest creature ever. It had big, strange ears, a reddish face and was extremely short. It was dressed in black, with boots in all colours and a hat with feathers in the colours of the rainbow. The most impressive thing he possessed was a lapel pin, which was a tiny mirror in the shape of a cloud.

- Good grace! A language disordered elf! Phoebus, I must be dreaming, said Iris.

- Jutht don't move farther ! Who are you and what do you want? And put it in your thilly heads that I am not an elf and thertailnly not dithordered, said the weird creature and took out of his pocket a glass stick that anyone who stared at for a while could see colours moving to all directions and could then be hypnotized.

-We are just children, said Phoebus, we were playing hide and seek in uncle Albert's attic, we went inside the wardrobe and then…..

-How dare you take me like a fool? Are you thpieth, thieveth of ideath and emothionth, tell me can you perform mathic or are you, representativeth of Hook? Do you want to thteal the new ideath and dithcoverieth?

-No, no, uttered Iris, we are just students and we are here to contribute to the t widely known and discussed 'Phenomena of Colours'.

-Yeth, but you were peeping into the houthe, I thaw you, and you are syth big liarth!

- Look sir, we can prove all we are saying, went on Phoebus. We have heard about the experiments on light and colors, we know certain things and we have come to offer help on the discoveries. We actually did not mean to peep into the room but it was so dark that we were able to find the entrance and…

-All righth, jutht thtop it and follow me into Newton'th lab to thtart work. You better be telling the truth, or else…

The weird creature continued uttering threats but Phoebus and Iris had no other choice than to follow it inside the house. The interior of the house was actually much bigger than the exterior and was divided in many small and dark rooms. It was very much like uncle Albert's laboratory but here everything seemed to be in place. In the first, there were transparent glass pots, a box containing signs of colors in Latin, white paper sheets and colored, transparent paper sheets. The second room was full of all different kinds of prisms and the third contained all the things that one could find in an artist's atelier. The last room was the darkest of all and was full of drawings and paintings of the sun, the moon, candles and many other light sources.

Phoebus and Iris, following exactly the directions they had been given, made paper lists of all the things in each room. When they finished with this, they sneaked into the room where the lectures were going on. Someone from the audience was now saying: 'As far as I know, there is a strong case, according to which light is power, action, property or a substance that is emitted by luminous bodies'. The man they had previously seen, stood again in the middle of the room and said: 'My conclusions about refraction, light and the properties of colors are based on the results of my experiments and not in hypotheses. Whiteness is the usual color of light. You see light is a combination of rays with all sorts of colors, as they are radiated from the various parts of luminous bodies. Thus, it can no longer be disputed whether colors are properties of materials that are visible to our eyes. It is not easy to determine exactly what light is and in what ways it produces visions of colors in our minds'.

There was silence once again, when a short hunch-backed man appeared, making some of the audience cheer: 'Welcome Mr Hooke!' Without wasting any time, Hooke said in a rather sarcastic tone: Dearest Mr Newton, hypotheses and scientific experiments cannot certainly be exclusively yours! Well, according to my conclusions, light is nothing else than a simple pulse or motion through a uniform and transparent medium; colour is nothing but the disturbance of that light, by the communication of that pulse to other transparent media. That motion starts by some other kind of motion in the luminous body: the dissolution of sulphurous bodies in the air, the action of air or by an external stroke such as in sugar, sea-water, or crystals that are mixed or rubbed. Then, the motion is blended with other motions that are produced in bodies during refraction. I believe that if Mr Newton had followed my thoughts, he would not find it so hard to understand refraction and colours.' The answer of Newton came straightforward from the other end of the room: 'All I want to say is that if I have seen further it is only by standing on the shoulders of giants….'

Phoebus and Iris stood completely silent and waited to see what would happen, when they felt a light tap just behind their knees. It was the weird creature again who had been looking for them all over the place.

-Here you are at last!

-We just,…

-Don't thay a word, follow me to the back of the houthe and collect ath many colored materialth ath you can, move on it ith an emergenthy.

The weird creature disappeared and Phoebus and Iris started to collect colored materials at the back of the house. As they were searching under a large pile of dried leaves they found a narrow passage that they could hardly walk in. They went through it and a feeling of emptiness surrounded them. They held hands and they started swirling all over again, heading towards an unknown direction. When the swirling stopped they realised that they were inside the wardrobe, in the same place that they had been playing hide and seek. This time they could hear someone banging on the door and the very familiar voice of their cousin:

-For God's sake, if you are in, just open the door! What have you been doing in here all afternoon?

Phoebus and Iris touched the door handle and the door opened at once. They followed their cousin who was demanding explanations without paying any attention to him. When they reached uncle Albert's lab they found him working again.

-Is everything all right guys? Can we call it a day for today? Phoebus and Iris, it is late, you have to go home.

Phoebus searched in his pockets, took out the paper lists he had made in Newton's laboratory and gave them to uncle Albert.

-Uncle, I believe that this will help you organize your experiments in a proper manner.

Uncle Albert took the lists and when he saw the Latin names of the colors and the classification of the materials, he could not believe his eyes.

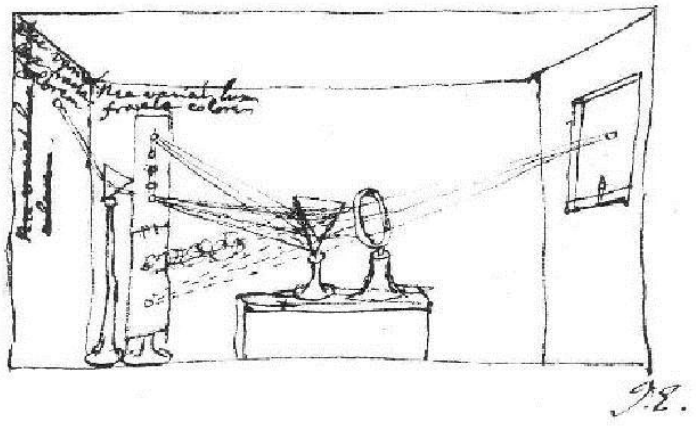
-How on earth did this happen? Where did you find this?

-It's a long story, said Iris in a sleepy voice.

-Look, said uncle Albert, almost whispering. This information you now have is extremely valuable. We will talk about it and start organizing our experiments tomorrow. Research has become your responsibility after this discovery.

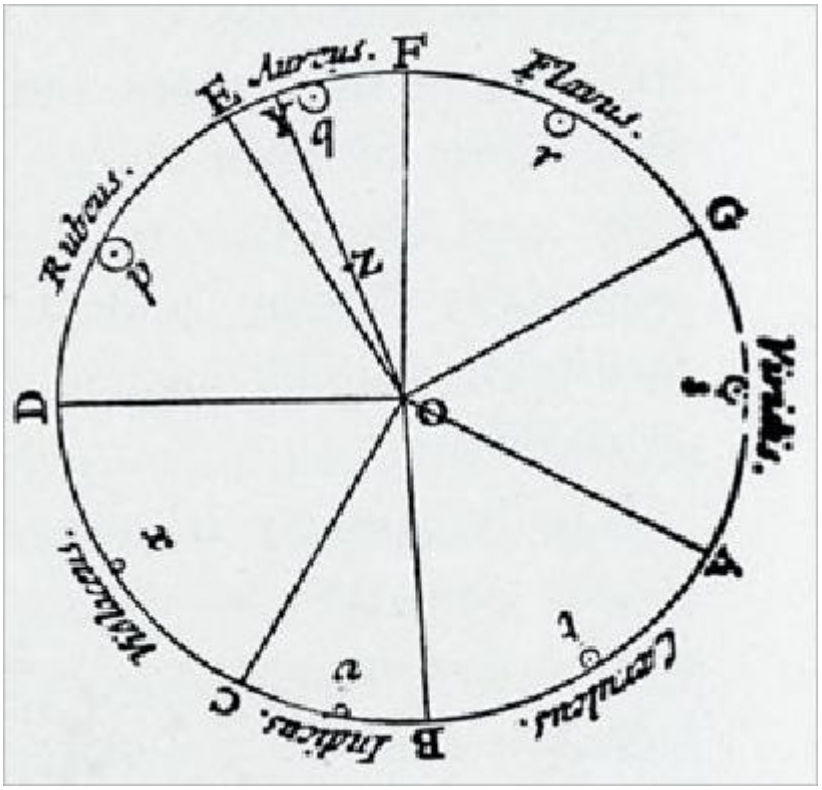
Phoebus and Iris agreed to visit uncle Albert the following morning and to start work immediately. It was already dark when they reached their house and the rain had stopped. They felt certain that the following morning, the sun would shine again all over the town and colors would return making people happy again. Maybe, if they helped uncle Albert and behaved themselves, uncle Albert would let them visit his secret garden at the back of the cottage, where they could catch the rainbow near the waterfall.

Appendix 2:



Picture 1: *Newton's drawing from P. Whitfield, Landmarks in Western Science,Routledge, 1999*

(http://www.astro.umontreal.ca/~paulchar/sp/great_moments.2.html)



Picture 2: Newton's color disc

Source: Newton, I. (1730/1979): Opticks, Dover Publications, Inc., NY1979 p.155

Appendix 3: Interview

Name:	Surname:	Year of Study:
Student Number:	School:	Date:

Questions:

1. Have you ever been involved in history of science or in a historical experiment as a student?
2. In what ways would you use it in a school classroom?
3. Which was the dominating element that your pupils liked in the story?
4. What happened during argumentation? In what way they did they make contact with the materials?
5. What were the cognitive obstacles that pupils faced connected with light and color concepts.
6. What were the pupils' ideas about light and colors?
7. What was the impact of Newton and Hook?
8. How did you, as a teacher, feel while you were presenting the story?
9. Evaluate the use of history of science for teaching light and color concepts.
10. Which part of the didactical scenario do you consider the most significant?
11. Did you obtain any knowledge about teaching Natural Sciences? Did you connect it with other fields of knowledge?
12. Comment on the value of the whole procedure for the designing of Natural Science activities.
13. Do you agree that arts (for example, literature and history) help understand the sciences?
14. If you were to redo the whole procedure would you make any changes?