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Analyzing Activities in the Course of Science Education, According to Activity Theory: The Case of Sound*

Xarikleia Theodoraki, Katerina Plakitsi
University of Ioannina, Dourouti, Greece

In the present study, we analyze activities on the topic of sound, which are performed in the science education laboratory lessons in the third-year students of the Department of Early Childhood Education at the University of Ioannina. The analysis of the activities is based on one of the most modern learning theories of CHAT (Cultural Historical Activity Theory). The use of CHAT contributes to the emergence of new and flexible ways of evaluating educational activities at European and global level. According to CHAT, the activity is not considered fragmented and isolated, disconnected from the socio-cultural and historical context that supports it. The subjects, rules, tools, and community learning do not operate in isolation, however, all parts/factors are in constant interaction. It is evident that a single change in the factors can cause a change in activity system. Furthermore, teaching and learning are influenced by socio-cultural and historical factors that coexist in the activities (Roth & Tobin, 2007). The analysis of the teaching of science activities to university students illuminates aspects concerning the development and reshaping of curricula from the first stages of education. The socio-cultural theory of CHAT, as a vital component of our ever changing society, contributes to the child's development as a future active citizen.

Keywords: CHAT (cultural historical activity theory), laboratory lessons of sound, science education, early childhood

Introduction

This research is connected with a wider research program of science education. The approach uses the CHAT (Cultural Historical Activity Theory) and focuses on a series of laboratory lessons of science education. This study approaches the problem of inefficiency of science education, according to the results of PISA 2009. It is an innovation which follows the transfer of the socio-cultural education in science education, supported by scientists around the world (Cole, 2006; Lee, 2004; Engeström, 2005; Plakitsi, 2008). In this study, we approach the concept of sound, as it is organized and carried out in laboratory lessons of the third-year students of the Department of Preschool Education of the University of Ioannina.

Activity theory is a cultural-historical theory, which was inaugurated by Russian psychologists, S. L. Rubinstein and A. N. Leontiev, in the early 20th century. It tries to explain the social and cultural work practices by associating them with the cultural and historical context in which this theory takes place. The basic

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Xarikleia Theodoraki, Ph.D. candidate, School of Education, University of Ioannina.
Katerina Plakitsi, assistant professor, School of Education, University of Ioannina.

unit of analysis as suggested by the activity theory is the activity itself. The rapid spread of information technology and therefore the HCI (human-computer interaction) led to focus on the terminal user. Designers very often face to the difficulties in identifying the problems of the user or the complex methodological conditions of application of new technologies where the users' needs are in the center. Activity theory can provide a framework, firstly, to re-interpret the users' needs, and secondly, to study the development and operation of different interactive systems that occur in each activity. Moreover, activity theory supports a hierarchical analysis of human action in the context of socio-cultural approaches. Nevertheless, the theory focuses on more flexible forms of hierarchy rather than static divisions of the "whole" parts.

When we refer to the activity, we do not just connect the "act"-"doing", but in transforming-mediating action translate a concept, "doing in order to transform something". We focus on the activity as a whole-system "activity system" (Engeström, 1987, 2000; Kutti, 1996). This underlying relationship between subjects and the final object is constructed and mediated by several factors, including tools, community, rules, and division of labor. It is, therefore, quite complex to one-sided and one-dimensional treatment of the activity theory. To tackle this obstacle, we adopted the triangular model of Engeström (1987), focusing on the object, which is constantly changing in relation to the objectives of the activity, but also manifests itself in different forms for different participants at different times of activity (Hasu & Engeström, 2000).

So, we focus on the subject-object which depends on:

(1) The different participants in the activity (subjects);

(2) The different phases of the activity (Hasu & Engeström, 2000).

Learning, knowledge, and expertise are distributed effectively through the involvement of people (subjects) in community learning (learning community). We notice that the notion of authority and specialization are disputed, as they are identified within each individual (subject). The thought is distributed, and therefore, can be redefined through social-cultural contexts (CHAT).

Our research, therefore, focuses on the implementation of activity theory in certain areas of science. As in other related studies, it aims at ratifying the activity theory as a tool for evaluating the scientific activities in different learning environments, such as classroom, laboratory lessons, university lessons, etc..

Rationale

In this study entitled the laboratory lesson LLSAT (Laboratory Lesson of Sound Based on Activity Theory), we conduct a research on the use and applicability of activity theory as an analytical tool for the activities of science education. Activity theory is a theory with expanding applications in various areas, such as science and science education in particular. The unit of analysis is the activity and students work in groups defined in the community, using intermediary tools for a common purpose. These objects play an important role in creating new concepts and ideas within the rules that the entire community follows. This makes the transition from one activity to another flexible and takes advantage of prior knowledge. Thus, the construction of knowledge is important for students who interact with each other and with the tools and resources within the community of students, but also in the activity (Engeström, 1999).

Our initial goal was to build the LLSAT laboratory, which is an attempt by the research team @ FISE in the Department of Early Childhood in the field of science education. We use the laboratory lesson as a methodological tool for preparing students to teach the topic of sound in preschool classes in the city of Ioannina. The basic point of LLSAT was our position on the educational success or failure that would use this

theory in collective activities in social context. The organization of LLSAT included the following steps:

(1) Awareness: At this stage, university students decide together for the theme that they will focus on during their practical training in preschool classes in the city of Ioannina, which will last two weeks. The sound was the most interesting and popular topic for university students. This is the stage where university students cooperate with each other for the same subject (sound) and they review the literature that will be needed. At this stage, the students record the concepts they know, and those who want to explore more on the subject of sound;

(2) Comparison: We compared the laboratory lesson of sound to previous laboratory lessons and the attitudes, as a result that knowledge and skills were built by university students. University students made a first comparison of the method followed in relation to the older more traditional methods;

(3) Exploration/activate prior knowledge: In this stage, we tried to capture the cognitive obstacles of university students when dealing with the issue of sound. Then, we conducted a bibliographical search on the cognitive obstacles encountered in children aged five to nine when dealing with the issue of sound;

(4) Creation: Having developed additional information about the sound, we created activities based on the needs of both university students and preschool pupils.

The university students used the prior knowledge on the subject to produce sounds with different objects. Then, they received more information about the properties of sound (intensity, hue, etc.) and put the materials into different categories, depending on how they produce sounds (ringing, blowing, etc.). Finally, they were asked to consider the cognitive obstacles that occur in five- to nine- year old children on the issue of sound and to reform the activities they chose to teach.

This study is part of a wider research, which uses activity theory as an analytical tool of science education activities. Through this intervention, we try to evaluate the activity theory as a tool for analysis of activities in different learning environments-classroom, laboratory courses (community), acting with different subjects—university students, preschool pupils, teachers, etc. (subjects). The research questions that concern us in developing the lab lesson of sound LLSAT during the intervention course were:

(1) What tools were used by subjects to capture the learning object and how?

(2) What were the rules used by the subjects?

(3) How was the division of labor related to the subject?

(4) What were the tools used by the learning community?

(5) What rules affected the learning community and how?

(6) How did the division of labor affect the way the learning community conquered the learning object?

The selection of teams that conducted the intervention was made by a sample of 80 third-year university students. Three pairs of university students were selected, which were assigned to teach the qualities of sound, and the production of sounds with different objects or body parts. University students were trained through:

(1) Laboratory lessons: A series of workshops on issues related to sound, its properties, the means, and the different ways of producing sounds;

(2) Lessons of science education: The lectures and the theoretical part, acted as support to the education of university students and aimed to familiarize them with issues from the field of science education;

(3) Individual and group work on the sound: Individual-group work was made at regular intervals, it helped groups of students interact effectively, work as a team, but also understand the methodological framework of activity theory, under which they would make the intervention in preschool classes.

Their training was evaluated:

(1) From the laboratory, courses through their work they had done, but also through their familiarity with concepts of science (sound);

(2) From the teaching intervention, they made in the course of their internship in preschool classes in the city of Ioannina.

The intervention took place in three different public preschools' classes in the city of Ioannina during the two weeks of practical training of students in schools. To do this, university students should follow the steps of the laboratory lesson of sound LLSAT that we had coorganized during the spring semester. At this point, we should mention that the university students had little previous experience of real class and had to work with 18 to 20 preschool pupils in each preschool class. Finally, we note that the contribution of the in-service teachers of preschools was very important, as they were willing to cooperate and assist preschool pupils on classroom management during the intervention.

Methods

We use the eight-step of Mwanza, so as to analyze our didactical intervention. University students participated in both the planning activities of the laboratory course, and their assessment according to the following eight stages of Mwanza (2001). The following assessment is a part of a wider research carried out and continues to be controlled by the @ FISE group of the Department of Early Childhood Education, University of Ioannina.

Activity of Interest (Activity of Interest)

At this stage, students define and choose the type of activity which most interests themselves and their pupils. Production of sounds with different objects and study the production of sounds with parts of the body, were the activities, which were studied and evaluated by both teachers and the students. At this stage, the organization of the workshop on the sound (LLSAT) took place.

The Aim of the Activity (Objective of Activity)

Students set the objective of activities in research and education. The findings resulting from the intervention were evaluated through filming and recording of the intervention carried out in preschool. Each group of students presented its findings and made comments on the outcome of activities.

Subjects Activity (Subject in This Activity)

The groups discuss about who were involved in the activity (students, teachers, parents, etc.). At this stage, they discuss about how the different objects were involved, the decisions taken and the different roles that evolved during the course.

Tools Mediate the Activity (Tools Mediating Activity)

Books, Internet, animations, and other materials were the tools with which subjects (students) used for the activities. At this stage, students reshaped the course of business, and redefined how to use different tools (tools) to better understand the properties of sound from the students. We note that the selection and use of tools (tools), which are common in everyday life, seemed to be very effective.

The Rules of Mediation Activity (Rules and Regulations Mediating the Activity)

Groups of students recorded: (1) the rules (rules) that they themselves chose to set the group (community); and (2) the rules chosen by the members of the groups of students to carry out activities. Each pair of students

worked together to explore different ways of producing sounds with different materials, and each pair recorded its findings. When students completed the nursery experimenting, they discussed their findings in class.

The Division of Labor as a Mediator in Business (Division of Labor Mediating the Activity)

The division of labor during the teaching intervention was divided into two categories:

(1) Master class: He showed how to make adjustments in order to place these activities (without actually affecting the substantive outcome of the results) also brought the class to take place around the discussion of results through interaction, posing probing questions (What happened? Which objects produce sounds? How can you produce sounds with your body and what conclusions can we make?);

(2) Students: Who worked in pairs, cooperated within their group as well as other groups to determine the properties of sound, which will be investigated and arranged in the pattern of instructional intervention.

Community in Which They Conducted Business (Community in Which Activity Is Conducted)

At this stage, they defined the environment in which the activity took place. More specifically, the environment, the community was the class of each nursery, which held the teaching intervention.

Results (Outcomes)

This is the final stage, which takes into account the results in the course of the teaching intervention. University students:

(1) Recorded their findings through questionnaires and interviews of students who made the teaching intervention;

(2) Processed and generated the data, both during configuration of LLSAT and during the intervention;

(3) Took account of the recordings (video, recordings, notes, etc.) during the practical exercises of students;

(4) Analyzed the activities of the teaching intervention, using activity theory.

LLSAT Summary

Students identify and describe different sounds and how each sound is made using simple materials and objects so as to explore the properties of sound (frequency, pitch, loudness, wavelength, and period). Students will be guided to experience how sound and volume change. LLSAT engages students in active learning experiences that build understanding of the properties of sound. Teacher-researcher points out the inquiry strategies as students discover the properties of sound and share their findings with the members of their group and with other groups. Scientific inquiry is occurring as students are learning content. Students also engage in a variety of experiences in which they explore, observe, and explain how sound is transmitted, reflected, and absorbed through a variety of materials. They also connect sound and sound properties with everyday life. Students also demonstrate that sound moves through different states of matter and observe that sound moves differently through different means.

Producing Sounds With Body Parts

Students start to produce as many sounds, as they can use different parts of their body. Students create a band of sounds with body parts (see Figure 1), which are divided into groups and each one agrees to produce the same sound with the cue of the teacher (e.g., one group claps, the second makes the sound “A” with the voice, and the third hits the knees).

The researcher-teacher encourages students to use different body parts to produce sounds. Each student

chooses the body parts which will be used for the activity. At this stage, students work individually and they have to cooperate with the researcher-teacher.

The interaction between the researcher-teacher and the students helps the mediation of the subject-object-tool system. We encourage students (subjects) to use the different parts of their body (tools) to produce different sounds. Students (subjects) make a sound with their hands, with their mouth, or by stamping their feet. The different types of sound that are produced (object) help students to understand the different type of body parts that will produce sound as well as the different sound that will be produced. The interaction that occurs among students is very important and the interactive system, subject-object-tool, allows both the students and the teacher-researcher to work towards a common goal-object.

The students produce sounds with different body parts (legs, hands, mouth, etc.). The teacher-researcher suggests that they: (1) use one body part each time; (2) make one sound each time; and (3) beat or wiggle one body part.

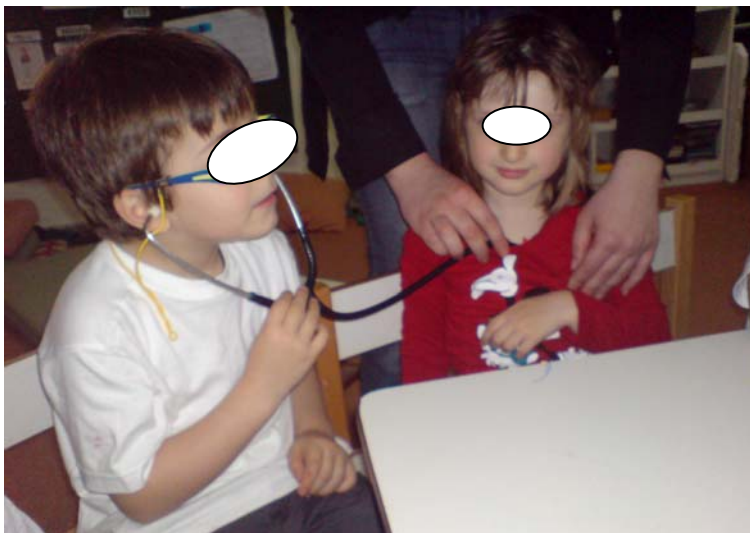

Figure 1. Children are listening to heartbeats.

The interactive system helps activate and involve students-subjects in the activity, and create rules within the group during the activity. Students (subjects) make rules (use one body part each time, create one sound each time, etc.) (object). The interaction of the subject-object-rule system help us to understand that the rules, as well as the tools, and contribute to achieving the object.

The researcher-teacher helps the group of students to choose the different body parts and lets them use it. Then students give instructions to each other about the way in which they will work (individually or in smaller groups). One student, for example, may be responsible for the hand clapping, another for the feet-stamping, etc.. Finally, a student can keep notes to record activity progress, and final to keep notes, indicating which body part makes the louder sound and which makes the quieter sound. In this interactive system (subject-object-division of labour), students-subjects cooperate during the activity and find ways to share responsibilities (division of labour) in each separate group. Some students may be responsible for different sounds, some others for the different body parts that the team has to use, and the rest of them can keep notes for the activity progress. The students-subjects as a group constantly collaborate with the researcher-teacher, who is also involved in the activity.

During the activity, the group of students interacts with other groups of students. It is, therefore, possible to ask some questions of the students in other groups, to determine differences between the use of different parts of the body to make sounds.

The interactive system learning community-tool-object could help the team to interact and share their data and their observations with other groups. The learning community could be the class, and the exchange tools (verbal, materials) help students collaborate, make different comments, and exchange their perspectives about the results of each group.

The groups of students decide which rules will be followed during the activity. They decide to: (1) use one body part each time; (2) create one sound each time; (3) collaborate with the other members of their group; (4) collaborate with the teacher-researcher; and (5) share and exchange their observations and data.

The following interactive system (learning community-object-rules) helps develop the activity. The rules (use one body part each time, create one sound each time, etc.) that students can use to develop themselves and promote better collaboration in 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 for the same activity, which leads to new interactive systems.

The groups of students record their observations and the results obtained from the outcome of the activity. They distribute their responsibilities within each group and present the results to other groups. The researcher-teacher encourages students to work in groups and gives details, only if the group requests them. Each group presents the different body parts and the sound that each part could create and explains their observation to the other groups.

The interactive system (learning community-division of labour-object) develops different functions for the members of each group (division of labour). The division of labour is formed in the wider learning community (community). The learning community is formed by students participating in the activity and the researcher-teacher (subject), who plays a supportive and cooperative role rather than acting as leader.

Producing Sounds With Different Objects

The researcher-teacher gives each student an object that produces sounds as follows:

(1) Shake (paper and flexible plastic);

(2) Crinkle (plastic glass and nylon bag);

(3) Tear (newspaper and magazine);

(4) Hit (chopsticks, spoons, and stones);

(5) Grate (grater and spoon, bottle with an uneven surface, and combs).

Students use objects to produce as many different sounds as they can (see Figure 2). Then, the researcher-teacher asks them to present a sound and the way it is produced (e.g., sound with hits).

The researcher-teacher also helps students to use the materials-tools (paper, flexible plastic, plastic glass, nylon bag, etc.) by giving them the opportunity to experiment freely with the materials. Each student uses the chosen materials. They may work together, creating smaller groups, and they may also cooperate with the researcher-teacher.

The interaction between the researcher-teachers and students helps the mediation of the subject-object-tool system. The students (subjects) use the materials (tools) as they wish and try to divide them into categories according to the sound that they create. During the activity, students observe the sounds created. They observe

the frequency, pitch, loudness, wavelength, and the period of each sound. The interaction that occurs among the students is important and effective, as it allows them to create smaller groups and choose materials and tools they want to use by setting rules. The interactive system subject-object-tool allows the students and the teacher-researcher to work towards a common goal-object.

Figure 2. Producing sounds with different objects.

Students experiment freely with the materials-tools (paper, flexible plastic, plastic glass, nylon bag, etc.). The teacher-researcher proposes:

(1) To use one object-material each time;

(2) To shake, crinkle, tear, hit, or grate the materials and observe what type of sound is produced;

(3) To place materials into groups according to their behaviour.

The resulting interactive system subject-rules-object promotes activation and involvement of the student-subject in the activity and the development of sequence rules within the team during the activity. The students (subjects) use rules (use one object-material each time, shake, crinkle, tear, hit, or grate the materials, etc.). The rules, as well as tools, contribute to reaching the final object, which may be different in each group. The object depends on the interests, desires, scientific knowledge of the group, and use of the materials.

The researcher-teacher helps the group of four students to choose the materials they want to experiment with. Then, he/she lets students to give instructions to their teams about the way in which they will work (individually or in smaller groups). One student may be responsible for the management of materials, another for the operation and use of different materials, or another may undertake to create categories in which materials are placed according to their behaviour (frequency, pitch, loudness, wavelength, and the period of each sound). Then, the students, as groups or as individuals, may describe the behaviour of the materials.

The resulting interactive system (subject-object-division of labour) helps subjects cooperate during the activity and find ways for sharing responsibilities (division of labour) in each individual group. The division of labour in each group depends on the students' ideas about sound and properties of sound. The students-subjects of each group constantly collaborate with the researcher-teacher. The students (subjects) can describe the

behaviour of the materials using the appropriate terminology (object). The object could be different for each student and for each group.

The groups of students that form during the activity collaborate. Each group has the opportunity not only to ask questions of the students in other groups, but also to collaborate with other groups, create larger groups, and share tools (paper, flexible plastic, plastic glass, nylon bag, etc.).

The interactive system learning community-tools-object may help the groups interact with and transfer data and observations to other groups. The learning community (student-teacher-class) could transfer and exchange tools (paper, flexible plastic, plastic glass, nylon bag, etc.). The exchange of tools (verbal, materials) helps students not only collaborate, but also make different observations, share the materials they have, and exchange perspectives after consulting the results of each group. In addition, groups record keywords and phrases pertaining to the subject involved, which helps obtain scientific knowledge about sound and the properties of sound and also use scientific procedures.

Groups of students set the rules that are followed during the activity. They decide to: (1) use one material each time; (2) to shake, crinkle, tear, hit, or grate the different materials; (3) place the tools materials into different groups categories; and (4) list on paper the materials in both categories.

The groups of students must write down their observations and the results obtained from the outcome of the activity. Having defined the responsibilities for each group, they present the results to the other groups. The role of the researcher-teacher is supportive, as he/she gives details only at the request of the students. Each group presents the properties of different materials used and explains to the other groups the way they decide to work with the materials.

The resulting interactive system learning community-division of labour-object displays the different functions that each group determines for its members (division of labour). Moreover, the division of labour is formed in the wider learning community (community) and in the individual community (groups). The learning community is formed by students participating in the activity and the researcher-teacher (subject), who plays a supportive and cooperative role rather than leading. The learning community can then be revised, and more students or students' classes can be added.

The Travel of Sound

Does sound travel through paper, plastic, or metal? The sound travels in air, liquids, and solids. Students put a ringing alarm clock in a paper bag, they close the bag and try to hear the clock ringing. They repeat the experiment using a plastic box and a metal can. They also try to experiment with the travel of sound into the water (see Figure 3).

They fill a glass jar nearly full of water, one student covers one ear with her/his hand and puts the other ear against the glass jar. Finally, another student hits two spoons together under water and the other student tries to hear the sound. Do they hear the sound that is produced?

The researcher-teacher gives students different type of materials (plastic box, paper bag, metal can, and a clock).

Students use different type of materials and try to observe the properties of sound in different conditions. The researcher-teacher also helps students to use the materials-tools (plastic box, paper bag, metal can, and the clock) by giving them the opportunity to experiment freely with the materials. Each student uses the chosen materials. They may work together, create smaller groups, and also cooperate with the researcher-teacher.

Figure 3. The travel of sound into the water.

The subject- object- tool system, mediate between researcher-teacher and the students, resulting the division of materials (tools) into different categories, according to their behaviour. The students (subjects) observe the hear of the sound and how loud it is (Is the sound heard in different types of materials?)

From the resulting interactive system learning community-object-rules, it is possible to construct the activity, as the rules set by students and followed by the groups making cooperation between groups easier and more effective. Furthermore, the rules ensure the mobility and interaction of the different groups that have emerged. The different effects-objects obtained in each group provides different aspects of the activity's outcome, and then lead to new interactive systems. The learning community within which the activity takes place is not a separate part of the broader learning community, but an integral part of it.

Results and Conclusions

During our cooperation with the university students, we noticed the importance of developing, implementing, and studying science education. We tried to offer both university students of the Department of the University of Ioannina and the pupils of preschool in the city of Ioannina, the opportunity to work with new and more flexible methods. Through design LLSAT, given to the third-year university students the opportunity to work at different levels of scientific method, using new concepts for the education (activity theory). Moreover, they were given the opportunity of collecting and processing data (empirical data) or as a comment, either through design of experiments (LLSAT) (Roth & Tobin, 2007).

The LLSAT provides many opportunities for students' discovery of objects and the sounds which they make.

During the initial evaluation of data and outcomes, the tools (tools) used by subjects to capture the learning object depends on both the cultural-social environment in which they work according to their own interests. This means that employees at three public preschool classes in the city of Ioannina discovered different ways to use the tools given to students. The cultural-social environment was a key to use these tools.

Furthermore, we mention that the rules (rules) were amended during the conduct of different activities. For this reason, the rules were recorded in four levels. Rules developed among: (1) students-students; (2)

student-teachers; (3) student-student groups; and (4) teacher-student teams.

We note that the division of labor among subjects concerns the management tools (verbal-materials). The tools we used in the learning community, help to achieve scientific literacy, active learning in the learning community and management of cognitive obstacles. Initial results (outcomes) show that the division of labor affects how the learning community (community) conquers the learning object (object), which varies depending on their interests and prior knowledge.

After LLSAT, the students could relate the pitch of sound to the length of a vibrating object and to define words (frequency, pitch, loudness, wavelength, and the period of each sound). They also examined hearing acuity using different materials and means. Moreover, we have to notice the importance of university students' training to use new tools and new learning methods and methodological tools, both in their own education and in their practical training in school classrooms.

The use of new methods of activities analysis by university students and prospective teachers marks the continuous and effective education and familiarity with these methods.

This research part, even limited, may be the growth driver of the science education in the early grades of education. The study based on Engeström's original model for the activity theory, focuses on the use and effectiveness of tools, which are associated with socio-cultural and psychological aspects of the tool. This approach emphasizes the importance of cultural behavior of the tool supported by the analysis of human activities using the tools.

The results of this study supported by the existing results of the teaching intervention LLMAT, which took place in preschools classes of the city of Ioannina (Theodoraki & Plakitsi, 2009). In conclusion, we note that the interference with the use of CHAT served as an opportunity to improve the teaching of science in the classroom. Furthermore, our collaboration with university students at the workshop gave them the opportunity to explore a real class and discuss the data collection with other university students, and preschool teachers involved in the teaching intervention. The most important part was that university students were able to design activities for science education and evaluate the progress of their teaching by using eight-step model of Mwanza (2001).

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