Argumentation in Science Education as a Systemic Activity: An Activity-Theoretical Perspective

Abstract

The main aim of the paper is to show that argumentation in primary science education can be exhibited not only as a collective activity, comprising of a series of discrete teaching and learning actions, but also as a systemic activity. This is achieved through an effort to reconstruct the activity of argumentation by examining both the ensemble of sociocultural practices that facilitate it and to reveal the dynamics and interrelations that exist between the activity's elements. Appropriate methodological and analytical tools from Cultural-Historical Activity Theory were used. The data to support the claim of the paper stem from an empirical study of examining the practices that facilitate argumentation in science education in six primary schools in Cyprus.

Keywords: argumentation, science education, activity theory, sociocultural, activity system, contradictions

1. Introduction, Rationale and Main Aim

In science education, argumentation is considered as a core skill that can empower young people to attain scientific literacy, develop their critical thinking, their reasoning, communicative and metacognitive skills and other subsidiary skills (Kelly & Takao, 2002; Jiménez-Aleixandre & Erduran, 2008; Berland & Reiser, 2009; Erduran, Ozdem, & Park, 2015). It can be developed either by explicitly teaching argumentation (e.g., Zohar & Nemet, 2002; Osborne, Erduran, & Simon, 2004) or by creating the conditions through which students would have ample opportunities to engage with argumentative discourse through appropriate activities (e.g., Duschl & Osborne, 2002; Kuhn, Kenyon, & Reiser, 2006; Martin & Hand, 2009).

Even though there is an abundance of research efforts in science education that present the various ways learning environments should be designed to support argumentation (e.g., Kuhn, 1992; Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Erduran & Jiménez-Aleixandre, 2008, 2012; Khine, 2012), argumentation realised as a systemic activity rather than a series of discrete actions taking place is an idea that has recently attracted researchers' attention but has not been studied much yet. In other words, most of the argumentation research studies reported in the literature (see Duschl & Osborne, 2002; Jiménez-Aleixandre, 2008; Manz, 2014 for a review of such studies), seem to deal with distinct elements that may facilitate argumentation in practice, such as the co-construction of arguments, epistemic tools to support students' inquiry, the development of written rubrics to construct and evaluate arguments, the production of written experiment reports, the explicit teaching of the argument's components or the use of portfolio (e.g., Bell & Linn, 2002; Jiménez-Aleixandre & Pereiro, 2002, 2005; Zohar & Nemet, 2002; Osborne et al., 2004; Sandoval & Reiser, 2004). Trends in the research literature (e.g., Erduran et al., 2015) do not define argumentation as a systemic activity comprising of interrelated elements and especially the often contradictory dynamics that may exist between these elements.

The importance of such an effort though is not ignored by scholars in argumentation research. As Jiménez-Aleixandre (2008) argues: *"the collective dimension of activity systems are relevant both for the design of learning environments to support argumentation and for the research about them"* (p.94) while Manz (2014) suggests that "*researchers need to develop classroom activity systems in which students' argumentation can serve an integral role*" (p.19). This seems to be in accordance with how scholars see other processes relevant to argumentation in science education, like the process of empirical inquiry, for which they argue that it "*cannot exist in isolation from the theories that it seeks to test, the analysis and interpretation of the data, and the arguments required to resolve conflicting interpretations*" (Osborne, 2014, p.579) and that a "*focus on collective activity*" (Kelly, 2008, p.105) is needed, as the production of arguments through scientific inquiry "*cannot be properly understood without knowledge of the sociocultural practices framing the activity*" (ibid., p.107). This, of course, is not something new in educational research, since some years back, Brown (1992) argued that classroom life should be considered to be "*synergistic*" and for which it is "*difficult to study any one aspect independently from the whole operating system*" as "*simultaneous changes in the system, concerning the role of students and teachers, the type of curriculum, the place of technology and so forth*" (p.143) can be observed. Additionally, Engeström argued that "s*chool learning is obviously a collective...activity system*" (Engeström, 1991, p.249) and that it "*is becoming increasingly complex and interconnected*" (Engeström, 1994, p.47).

Nevertheless, previous work that introduced the idea of argumentation as a collective whole (Jiménez-Aleixandre, 2008; Kelly, 2008; Manz, 2014), only addressed this idea either as an urge to researchers to use a wider lens for facilitating or examining argumentation in science education by having its collective, sociocultural dimension in mind or as an effort to consider ways of re-embedding argumentation as a tool and a meaningful scientific practice in science education, similar to those taking place within professional scientific activity systems; suggestions with which we are in complete accord.

The main aim of this paper is to show that argumentation can be exhibited not only as a collective activity, comprising of a series of discrete actions taking place in primary science education, but also as a systemic activity, and that this sense of argumentation can be observed if the appropriate analytical lens is used. This means that we will not only attempt to reconstruct the activity of argumentation by looking at the ensemble of sociocultural practices that facilitate it, which in essence would not differentiate it from other studies (for example, Kelly, 2008), but also attempt to reveal and portray the inherent dynamics and interrelations that exist between the activity's elements. To achieve this, we will use appropriate methodological and analytical tools from Cultural-Historical Activity Theory (CHAT). The data to support our claim stem from an empirical study of examining the practices that facilitate argumentation in science education in six primary schools in Cyprus. The importance of realising argumentation as a systemic whole rather than a collective formation of discrete actions lies in the realisation that a systemic activity is more than the sum of its discrete actions and therefore, cannot be adequately explained by noticing these actions alone while ignoring the inherent dynamics and connections that may exist between them (Leont'ev, 1978).

2. Theoretical Framework

2.1 Human Praxis in the Form of Activities

According to CHAT (e.g., Vygotsky, 1978; Leont'ev, 1978, 1981; Engeström, 1987), human praxis should be realised in the form of activities, because individual actions are insufficient to explain human behaviour and may appear meaningless outside the collective activities in which they occur. Activities are realised as systemic wholes driven by an object, which is said to be the activity's main motive. They represent the voices of multiple stakeholders and are formations that have been shaped through long periods of time. Additionally, activities are said to be inherently contradictory, as multiple tensions may be noticed within or between the elements that comprise them. Relevant to argumentation, this would suggest that we should not seek to understand how argumentation is practiced in the classroom by only looking at the discrete teaching and learning actions that facilitate argumentation in isolation to one another. We should instead allow argumentation to reveal itself in its totality by examining the multiplicity of motives, instruments and social practices that have historically shaped this activity within the sociocultural context in which it is being facilitated and the inherent dynamics and interrelations that exist between these elements. CHAT is seen as a framework that may offer appropriate theoretical, methodological and analytical tools for examining the societal and systemic character of the activity of argumentation, such as the activity system and the notion of contradictions, as described in the next section.

2.2 The Activity System

Engeström (1987) expanded Vygotsky's (1978) basic mediation model to a more complex unit of analysis; a collective, multi-voiced, artifact-mediated and object-oriented system, referred to as the activity system (Figure 1). The activity system was supplemented by additional components, which derive from the ongoing interaction of the individual with and within the social surroundings; these are the components of the rules, community and division of labour.

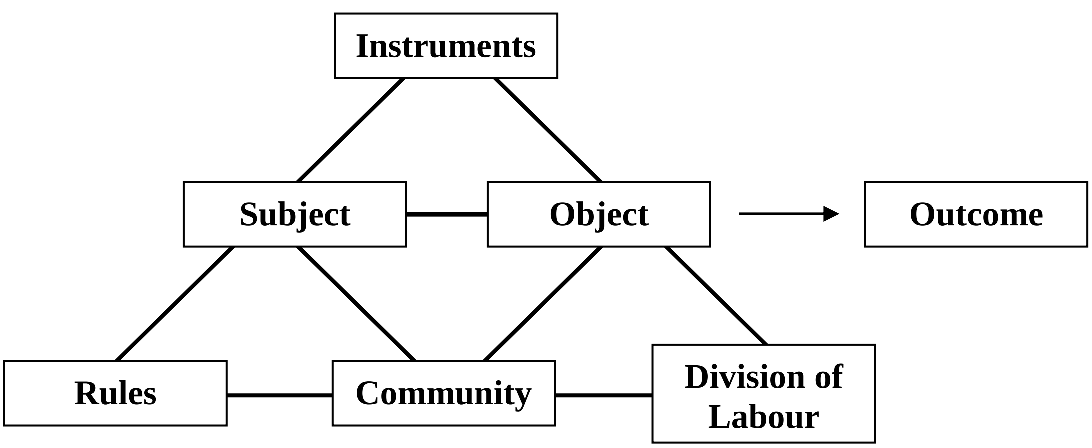


Figure 1. The expanded activity system model (Engeström, 1987).

The object is the motive and the driving force of the activity. Although activity systems do not have a single subject, they are being observed and interpreted not only through a subjective (in the sense of one subject) but also through a systemic lens. Nevertheless, it is sometimes considered as good practice to analyse the system that concerns a specific subject in order to realise the subject's needs and motives. Instruments include tools, which are externally oriented, and signs, which are considered to be a sub-category of psychological tools. Rules refer to norms and conventions about how certain things are being decided within the system and exist in order to ensure shared responsibility and cooperation between the participants. The division of labour refers to how the labour is divided within the community or between the subject and the community. The community functions as a social group and mediates the interaction between the subject with the rules or the division of labour and the object. There is thus, an ongoing mediation of continuous interactions that exist within and between the activity's constituent components. The projected outcome of the activity system can function as the activity's motive which gives meaning to actions (Engeström, 1996).

Activity systems are said to be internally contradictory since contradictions may be observed either within or between the components of a single system or between interacting activity systems. Contradictions are not mere problems within the activity but "*historically accumulating structural tensions within and between activity systems*" (Engeström, 2005a, p.137); we should distinguish that is, between a tension that may be noticed as an isolated event and a tension that is repetitively being experienced by participants. For the scope of this paper, two types of contradictions, described by Engeström (1987), were used, mainly as analytical tools: primary contradictions, defined as tensions within each constituent component of the activity system, and secondary contradictions which exist between the constituent components of the system.

3. Methodology

The research methodology derives from the expansive learning theory (Engeström, 1987, 1996, 1999), which is said to be an application of CHAT (Engeström & Sannino, 2010). One of the many ways the theory can be materialised in practice is through the learning actions of an expansive learning cycle (Engeström, 1999a; Engeström and Sannino, 2010) (Figure 2). The starting point is when participants in the activity begin to question the seemingly problematic established practice, seeking for new possibilities. The researcher's effort then is to be informed about the situation and the problems that exist by performing a thorough historical analysis of the activity, modelled with the help of the activity system model, in an effort to trace the activity's origin and its previous developmental phases. Contradictions that may have induced these developments are also identified. Following this, qualitatively new models are formulated and examined in practice by the participants so that they can be further enriched and conceptually extended, reflected upon and evaluated, in an effort to achieve a new stable form of practice, freed from contradictions that may have existed.

As the study is part of a bigger research project (Lazarou, 2012), processes that only fall into the learning action of historical analysis are presented in this paper. During this phase, an effort was made to thoroughly examine and portray in a historical way the classroom practices that facilitate argumentation in science education in six primary schools in Cyprus and to recognise any tensions induced by or existing within or between these practices. This thorough examination would allow us to possibly unveil and reconstruct argumentation as a systemic activity, which is our paper's main aim.

For the scope of the research, argumentation was regarded as the process of evaluating and justifying claims (Naylor, Keogh, & Downing, 2007), considering the production both of rhetorical (Newton, Driver, & Osborne, 1999) and dialogic arguments (Driver et al., 2000). Also, following a similar definition by Conner (2007), an argumentation episode was regarded as any episode from the science education lesson that involved the students' effort or the collaborative effort between the students and the teacher to build an argument which consisted of a claim and any sort of supporting utterances, any relevant sub-arguments and any additional support from any other source (e.g., an illustration, a graph).

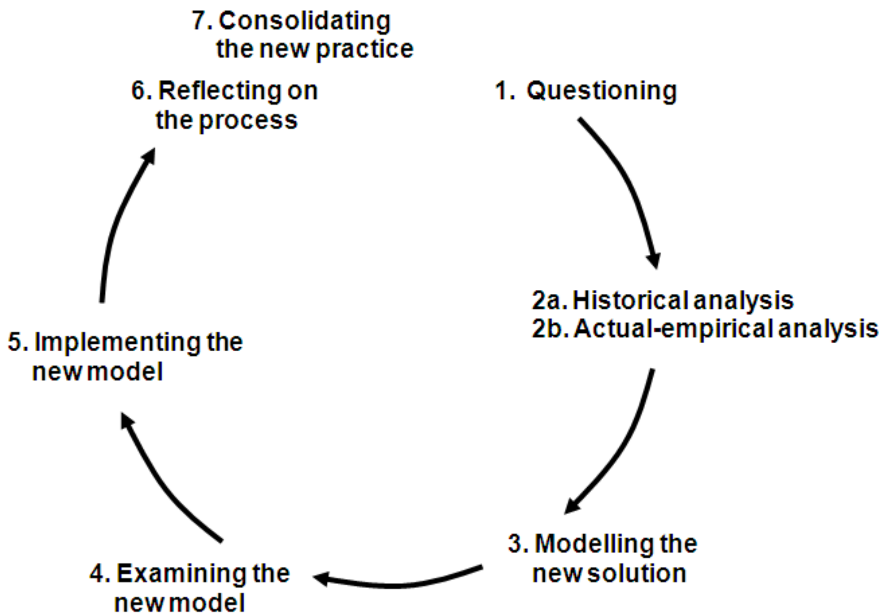


Figure 2. Sequence of learning actions in an expansive learning cycle (Engeström, 1999a, p.384).

3.1 Data Collection

As the study's main effort was to reveal all the instruments, rules and social practices used to support argumentation in primary science education, we used a number of data sets, as favoured by the methodological guidelines deriving from CHAT (Nardi, 1996): (i) a yearly "Self-Reflective Teaching Diary", recorded by the first author while being a full-time teacher who taught science education in two primary schools in Cyprus, (ii) observation of four 80-minute science education lessons in four other primary schools during the same year, (iii) semi-structured interviews with the Science inspector and five teachers who regularly taught science education in Year-6 and (iv) an examination of the questions in the Year-6 science education students' textbook and evaluation booklet.

Through the yearly "Self-Reflective Teaching Diary", argumentation episodes taking place during science education were regularly noted during the year the research was running; these were recorded in the form of written accounts that functioned as the teaching diary of the first author. One of the reasons for using a yearly diary was to lengthen the study's time-span, as other researchers have done (e.g., McNeill, 2011; Ryu & Sandoval, 2012), and overcome the limitation observed in other studies which focused on the argumentation observed during single episodes. Forty four episodes were gathered and four of these are presented as examples in Table 1. In framing argumentation in the data presented in Table 1, we were guided by Walton's (1996) categories. Relatively few studies have chosen to use Walton's framework of presumptive reasoning and categories of argumentation (e.g. Duschl, 2008; Ozdem, Cakiroglu, Ertepinar, & Erduran, 2013). The predominant definition of argument in science education (e.g. Osborne et al., 2004; Jimenez-Aleixandre, 2008) has relied on the work of Toulmin (1958/2003) who provided a structural account of the argument consisting of the claim, the data, the warrant, the backing and the rebuttal.

The four 80-minute science education lessons were observed in four separate primary schools, three located in Nicosia and one located in Limassol which are the two most populated cities in Cyprus. The four teachers who performed the lessons were teachers who regularly taught primary science education for at least five years; we will refer to them as Teachers 1, 2, 3 and 4. During these lessons, an effort was made by the first author who observed the lessons, to document, in the form of notes, any argumentation episodes that occurred. Two of the lessons observed were conducted in Year-5 classrooms, involved the subjects of "Eyes and Vision" and "Expansion and Contraction of Liquids" and were performed by Teachers 2 and 4 and the other two lessons were conducted in Year-6 classrooms, involved the subjects of "Acids and Bases" and "Electromagnetism" and were performed by Teachers 1 and 3.

The semi-structured interviews with the Science inspector and the five teachers (Teachers 1, 2, 3, 5, and 6, with Teachers 1, 2 and 3 being the ones that their lessons were observed), were conducted in an effort to comprehend the whole sociocultural context in which argumentation was facilitated, in accordance with the theoretical and methodological underpinnings of CHAT (Engeström, 1987). Therefore, the questions asked aimed at exploring issues that related to the six constituent components of the activity system model (see Figure 1) and aimed at revealing a detailed account of how argumentation is facilitated in science education.

Finally, questions located in a Year-6 science education textbook and evaluation booklet were examined in order to realise whether they facilitated argumentation in any way and whether they included any elements for supporting students' argumentation efforts.

3.2 Analytical Processes

The analytical methods used for analysing data collected are common to the ones used in various research studies within the CHAT doctrine (e.g., Engeström 1995, 2000, 2001; Collins, Shukla, & Redmiles, 2002; Edwards & Apostolov, 2007; Ellis, 2008, 2010). Engeström (ibid.) emphasises the importance of the concept of the activity as a unit of analysis so that any interpretations made, deriving from a discourse analysis concerning the various actions of the participants, takes into consideration the systemic activity in which they evolve. In this way, the scope of the analysis is neither too narrow nor too wide. Engeström (ibid.) proposes that the activity system model itself (see Figure 1) is a structural and visual aid for schematically describing the series of successive actions in the activity system while helping us organise our analysis to focus on the major themes that need to be addressed, which are the activity model's components.

Therefore, the main aim of our analysis was to realise the series of successive actions through which argumentation is practiced in primary science education in Cyprus by using an activity-theoretical discourse analysis and organise our analysis by using the activity system's components (see Figure 1) as our main themes of analysis. This line of analysis was followed with all datasets collected. However during the analysis of specific datasets, we also used additional sub-categories as coding categories to characterise the various argumentation actions that were identified, described in the following paragraphs.

During the analysis of the entries in the "Self-Reflective Teaching Diary" and the observation of the four science education lessons, we also used Walton's argumentation schemes (1996) as coding categories for characterising the different strategies students use when building arguments. For example, if an argumentation episode fitted the definition of "*Argument from Analogy*" (Walton, 1996, p.77), it was coded as such in the analysis. Additionally, supplementary coding categories (e.g., "references to pre-existing content knowledge", "question prompts") were generated from the data by using inductive analysis (Thomas, 2006). Table 1 presents a number of examples of how the analysis was performed. All the sub-categories deriving from the analysis of the "Self-Reflective Teaching Diary" and the observed lessons were then schematically portrayed within the specific components of the activity system model.

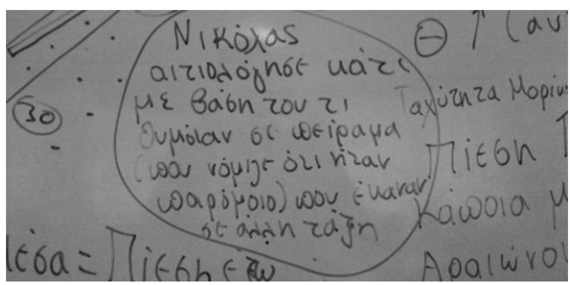
The analysis of the questions in the Year-6 science education textbook and evaluation booklet aimed at identifying the instruments available to students when building arguments. Each question, alongside any accompanying element (e.g., pictures, tables), was regarded as the unit of analysis. Initially, these questions were categorised in three groups, which inductively emerged from a pre-analysis:

i. questions that required students to engage in argumentation or follow the steps of scientific inquiry, which is a process that is said to support argumentation (Driver et al., 2000),
ii. questions that required students to provide a descriptive account, either of a phenomenon already described in the textbook or of an image or diagram presenting a specific situation and,
iii. questions that required students to engage in procedural inquiry through which they had to follow pre-given instructions to answer the question or support a pre-given statement.

An initial coding was used to distinguish between these three categories of questions: "Argumentation Question", "Descriptive Question" and "Procedural Inquiry". In total, 71 questions were examined. Subsequently, questions classified as "Argumentation Questions" were further analysed by examining the type of support provided by each question that seemed to assist students' argumentation effort (picture, description, procedural inquiry guidelines, model, graph or/and table, given claim/claims).

Table 1

Examples of entries in the "Self-Reflective Teaching Diary" and coding used for analysing them

Entry or Extract from an Entry in the "Self-Reflecting Teaching Diary"	Coding
Note 11: While doing our lesson, we were discussing about how can students protect their teeth and reduce the risk of tooth decay after eating a sweet, when they do not have immediate access to their tooth-brush and tooth-paste. We discussed a few things and a student suggested eating a gum after eating our food to protect the teeth. We showed a packet of sugar-free gums and discussed that this kind of gums could help reduce or neutralise plaque acid and gather the food debris from our mouth after eating. Some of my students strongly opposed to this idea. They told me that it is not a good thing to eat gums as the head-master of the school once told them that eating gums could destroy their teeth and she prohibited them from eating gums at school. To support their argument, the students told me that the head-teacher had told them that her dentist had given her that advice. A heated discussion followed in the classroom through which these students could not accept any reason for eating a gum to protect the teeth, even though we said that we could consume sugar-free gums wisely in order to protect the teeth after eating and maybe the head-teacher and the dentist were talking about non sugar-free gums or maybe our head-teacher had a particular teeth problem that eating gums could actually be bad for her teeth. The fact that the head-teacher of the school told them that was enough reason to make them argue otherwise.	Argumentation Scheme: **Argument from position to know** or **Argument from Authority** (head-teacher) or / **Argument from Expert Opinion** (dentist) ➔ ***"Instruments"*** (Students' Activity System)
Note 23:  Note taken on the classroom's white-board to stimulate discussion among students on the validity of an argument presented. I recorded what the student had said: *"Nicholas based his argument on an experiment he remembers from last year and thinks that what we are doing now is similar [to that experiment]."*	Argumentation scheme: **Argument from analogy** ➔ ***"Instruments"*** (Students' Activity System)

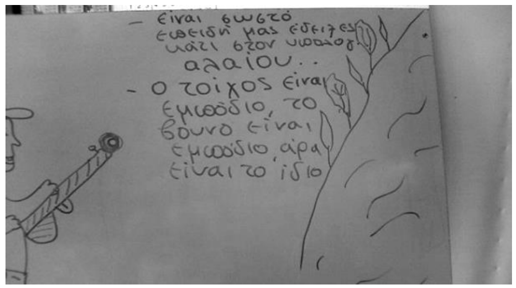
Note 26:

Today, when students tried to build a written-argument to support why a dam's wall is built having increased thickness at the bottom (in relation to the increased depth of the water and therefore the increased hydrostatic pressure), I realised by looking at their answers that those students who had grasped the concept of hydrostatic pressure and remembered what factors may influence it could build more valid and complete arguments than those students that could not recognise that the phenomenon (the dam) was linked to the concept of hydrostatic pressure.

Reference to pre-existing content knowledge / Argumentation Scheme: **Argument from Cause to Effect**

- ➔ ***"Instruments"*** (Students' Activity System)

Note 31:



"*The wall is a barrier. Mountain is a barrier. Therefore it is the same*" (6th-grade student). Argument expressed by a student when discussing about whether we could produce echo in our classroom. It was recorded on the whiteboard to stimulate discussion among students.

Argumentation Scheme: **Argument from Analogy**

- ➔ ***"Instruments"*** (Students' Activity System)

Note 39:

I notice that a significant factor that seems to influence students' ability to develop an argument, and especially their effort to put forward supporting data and warrants, is prerequisite content knowledge. In the electricity test that I gave them today, there was a question that asked children to build an argument on what would happen in a circuit with light bulbs connected in series if one of the light bulbs burned out. Some of my students based their whole argument on the knowledge concerning light bulbs connected in parallel, which is not relevant knowledge to what the question was referring to, and thus produced an invalid argument. Whereas, other students that seemed to have understood the prerequisite knowledge concerning the circuits with light bulbs connected in series could easily produce a valid argument e.g., "*If lamp number 3 is burned out, then none of them will light since they are connected in series because in this kind of circuit when one is burned out then all the others stop working*" (Tasos, Year-6).

Reference to pre-existing content knowledge / Argumentation Scheme: **Argument from Cause to Effect**

- ➔ ***"Instruments"*** (Students' Activity System)

4. Findings

The findings, in line with the main aim of the paper, focus on an attempt to unveil and reconstruct argumentation as a systemic activity. They are reported through dedicated sections that refer to each dataset collected; the aim of this fragmentation is first, to illustrate the gradual reconstruction of argumentation as an activity system and second, to avoid any confusion regarding the analytical source of each finding due to the multiple datasets used.

An important clarification that needs to be made is that two discrete activity systems were constructed. One was used to represent the activity system of argumentation representing the students' perspective and the other to represent the teachers' perspective. To validate the claim that these were indeed two discrete activity systems, we turn to the theoretical tools that CHAT offers and specifically to the notion of the central and neighbour activities (Engeström, 1987). Our central activity system should be regarded as the one representing the students' perspective; it is the one being examined and the one that our object, that is argumentation, is embedded in. The system that represents the teachers' perspectives fits the definition of neighbour activity systems as it is the one in which the object of our central activity is embedded, the one which produces the instruments of the central activity and the one that includes activities which are somehow related to the central activity, such as rule-producing activities.

4.1 Evaluation of the Interviews of the Teachers and the Science Inspector

The aim of the analysis of the interviews was to gather evidence that would potentially enable us to exhibit argumentation as a systemic activity. Any generalisations or inferences made are descriptively presented and accompanied, when needed, by supportive data.

What is considered as the object of the activity of argumentation in primary science education, argumentation that is, was defined similarly by the participants: an important skill that students should have or attain in order to cope with the scientific knowledge they obtain, either for expressing this knowledge by using the appropriate scientific terms, for making the links between scientific facts they learn, or for transferring the attained knowledge into instances of their everyday life. The Science inspector highlighted argumentation's importance by stating that it is "*one of the most basic skills that a student should have and it needs to be acquired when students are in primary school and year by year be evolved and improved*". Furthermore, some of the teachers insisted on the difference between attaining scientific knowledge and expressing this knowledge as part of an argument, which is what they regarded as the essence of argumentation. As Teacher 1 suggested: "a*rgumentation is a skill...the mechanism...they cannot express the attained knowledge if they don't have this skill...and cannot connect the pieces together"*; a view that Teacher 3 seemed to agree with since he supported the idea that scientific knowledge *"is necessary only if they can make the right links*" through argumentation. Additionally, Teacher 2 argued that it is important for students to be able to provide sufficient arguments because *"when students can argue about something and provide reasons, it means that they have attained the knowledge"*.

Concerning the instruments students use to argue, all teachers referred to the use of pre-existing knowledge as the main tool that students use, even though Teacher 1 noted that pre-existing knowledge alone is not enough for students to build a sufficient argument:

> Soil contains air. When they had to use this, they couldn't use it...to provide an argument for one of the examples I gave them. And it was easy. Therefore, it's the mechanism that they didn't have...the mechanism of reasoning; that they had to connect these all together.

Teachers 3 and 5 seemed to agree with this view. Teacher 6 also noted that students might refer to observations they make during experimentation as evidence to support an argument. Teacher 2 reported that her students bring examples from their everyday life or make references to what they see in movies or documentaries to support a claim:

> Researcher: What kind of reasons do students bring forward to support their claims?
> Teacher 2: From their everyday life. For example, when we were dealing with friction, they were referring to various things...they told me that their mother was mopping the floor and she slipped, because there was water and you may slip because of that. They were telling me various things from their everyday life or from movies and documentaries they saw.

Concerning the instruments teachers use to help students argue, teachers noted similar methods. A prominent instrument mentioned was the use of prompts and question prompts. As Teacher 3 reported, *"it has been one of my main characteristics, I mean, I was a fan of "why, why", and this year my students named me as "Mr. Why*". Teachers 1 and 2 also noted that even though an argumentation question in students' textbook might not include a why prompt, they felt that they had to explicitly prompt their students to reason with such a prompt. As Teacher 1 stated:

> They will answer a question you ask them as briefly as possible...I had to ask them beforehand "and why" or I had to insist on using it...Will the magician be pierced? No, he won't. I had to ask them "and why".

Question prompts might also include, as teachers reported, phrases such as "*yes, what do you mean...do you want to add something?*" (Teacher 6), "c*an you provide reasons for that?*" (Teacher 2) or include "*some hints to help them express themselves, if they are trying to show that they have sort of an argument*" (Teacher 3). A drawback of using multiple question prompts, as Teacher 1 underlined, is that students might get confused or might not realise how the question prompts posed to them link back to the initial question:

> We tried to realise this with questions and answers. By using a question, I asked them what the bubbles were. They were air. Think about it a bit, I told them. But this was just one question though. Let's say that I had to ask more questions, I would have lost them until I went back to the initial [question].

Moreover, teachers' efforts to support students' argumentation might also include, as Teachers 2, 3 and 6 reported, prompts so that students use terminology or content knowledge they came across during the lesson or during previous lessons, a re-statement of the question or explicit explanation of what the question asks if students seem to not have understood this. Moreover, Teacher 6 added that he would also refer to experimental results if he thought that this might be useful for his students to build their argument. There were also cases, as Teacher 2 reported, that she had to repeat the whole experimental process to help students who were not convinced by the experimental results in order to use them as data for building their arguments. What is important in helping students express complete arguments, as Teachers 1, 2 and 6 suggested, is to be persistent in asking for supporting reasons for a claim given: "*You have to insist; you can't do anything else really*" (Teacher 2). Furthermore, as for the criteria that teachers have to assess the adequacy of students' arguments, Teacher 3 said that his feedback depended on the knowledge he had for each student's capabilities:

> Researcher: How did you decide at those moments when they were trying to provide an argument, that their argument was adequate to decide whether you will support them?
> Teacher 3: It depended on who was saying that argument, his achievement level in Science and the way he can express himself verbally. For example, I had a student that she was a top student in written tests, but she never answered anything verbally. When she raised her hand to tell me an answer, I told her: "because I know who you are and what your capabilities are, your argument is not adequate and you should expand it".

Finally, the Science inspector's view concerning the teachers' role was that it depends on the skills of each teacher to facilitate argumentation in their teaching, regardless of the subject they teach. In more practical terms, the Science inspector suggested that teachers must design and organise their lesson appropriately so that they can first help students acquire the necessary content knowledge regarding the relevant scientific phenomenon, then pose an argumentation question to them and gradually help them understand the question and build a sufficient and valid argument to address it.

There was also a reference to the role of group work in relation to argumentation, related to the component of the division of labour. Teacher 3 for example, reported that group work may help reserved students express themselves and engage with argumentation in a productive way:

> There are students that cannot express themselves but, through group collaboration, they find a way to express what they want to say. One of my students is very shy, very, very shy and she wants to say many things but she doesn't have the courage to do so. Her friend, who is an extrovert, helps her interact and they form nice arguments together.

Bold text in Figures 4.1 and 4.2 illustrates the various elements of the components of the activity system of argumentation, as these were descriptively presented by the teachers and the Science inspector during the interviews.

4.2 Evaluation of the "Self-Reflective Teaching Diary"

The analysis of the episodes reported in the "Self-Reflecting Teaching Diary" revealed the aids that are available to students or are being offered to them to engage with argumentation. As mentioned, these were characterised in terms of Walton's argumentation schemes (1996) and in terms of supplementary coding categories (see Table 1). In activity theory terms, these aids were classified as elements in the various components of the activity system of argumentation. To avoid repetition, we present the findings of this analysis through Figures 4.1 and 4.2 by using text in *italics*. Text in both **bold and *italics*** refer to elements that both the analysis of the "Self-Reflective Teaching Diary" and the analysis of the interviews revealed.

4.3 Evaluation of the Lessons Observed

As for the ways teachers employ to support students' argumentation efforts, the analysis of the notes taken during the observed lessons showed that teachers make use of scientific inquiry, which is said to support argumentation (Driver et al., 2000), and of simple prompts and question prompts to help the development of the discussion between them and the students. Moreover, in one of the cases, Teacher 4 encouraged her students to make use of pre-existing knowledge or use observations from the experiments performed as pieces of data or backing in order to support their initial claim. Table 2 illustrates examples of the scaffolds Teachers 4 used to support students' argumentation efforts. No reference is made to extracts from the lessons of Teachers 1 and 3, as no noteworthy argumentation episodes were observed. Additionally, Teacher 2 was using supportive utterances that could be characterised as warrants, based on the definition of the argument given by Toulmin (2003), in order to assist her students draw the conclusion and complete a claim-data argument that was expressed; the claim is regarded as the initial assertion in which we commit ourselves, data as the facts that seem to support this initial assertion and the warrant as the supplementary and explanatory statement that helps us validate and authorise the step we took to present certain data as the basis of a certain claim. An extract from the lesson is quoted as an example:

> Teacher 2: Why do we have eyebrows? Are they really necessary?
> Helen: When sweat runs down, not to get in the eye.
> Teacher 2: When sweat runs down, not to get in the eye. Therefore, the eyebrow is there to protect the eye from sweat. Does anyone have a different opinion? How can we check what Helen told us with an experiment? Who can tell me? Marios?
> Marios: We will take the pipette, put some water here and let it run down [*on the forehead*] and if it stays on the eyebrow, it means that the eyebrow absorbs the sweat.
> Teacher 2: Can someone say again the experiment that Marios suggested?
> Ileana: To put some water here and to let it run down.
> Teacher 2: And how can I realise that the eyebrow is there to protect the eye? Danai?
> Danai: If it does not get through our eye, it means it can protect it.

The teacher is completing a claim-data argument with a warrant; that it is "*necessary to have eyebrows* [claim]…*when sweat runs down, not to get in the eye* [supporting data]", since "*the eyebrow is there to protect the eye from sweat*" [warrant]. Furthermore, it was shown that Teacher 2 was extensively using counter arguments for triggering further discussion or for helping students understand the fallacies of their arguments (see Table 3).

Conclusively, as illustrated through the lessons observed, teachers made use of a variety of scaffolds to support students' argumentation efforts; these included the scientific inquiry method, question prompts (mostly why prompts), simple prompts, warrants, counter arguments, acquired content knowledge and observations from the experiments performed. These are presented in <u>underlined text</u> in Figure 4.2.

Table 2

Various Scaffolds Used During the Lessons

	Extract from the lesson	Type of scaffold used (Coding)
1	Teacher 4: How can you explain this Nicky?	*Use of Question Prompt:* Teacher is using a question prompt to help the student present data to support the claim.
2	Teacher 4: Nice. Do all liquids expand in the same way? Here's your answer [*Teacher is nodding at the experiment she is performing*]	*Use of observations deriving from the experiment:* Teacher encourages students to backup the claim based on observations made concerning the experiment.
3	Teacher 4: No is not a satisfactory answer.	*Use of Simple Prompt* - Teacher encourages student to backup the initial claim with data.
4	Student: Because the sun produces heat during the summer, and because gas is a liquid, it can rise and... Teacher 4: What will happen? What will happen to the gas? Its volume will...?	*Use of Question Prompts:* Teacher is using question prompts and questions with missing words to encourage her students complete their claim.
5	Teacher 4: Gas will be spilt out of the reservoir. However, you have not thought of something else. Why is gas going to spill out of the reservoir, since something else expands at the same time? You have not thought of something else. The answer that you gave was correct. I should not fill my reservoir with gas, because gas is a liquid and when it expands it will be spilled out of the reservoir. But now, I am telling you to think something that we learnt during the previous lesson; what else does expand?	*Use of Simple Prompts and Why Prompts:* The teacher encourages her students to revise the argument they have given in light of a new variable she introduces to the discussion. *Pre-existing knowledge:* The teacher encourages her students to draw on previous knowledge they acquired.

Table 3

The Use of Counter-Claims as Argumentation Scaffolds

	Extract	Counter-Claim located in the extract
1	Teacher 2: Which out of the five sense you consider as the most important and why? Student 1: Sight. Teacher 2: Why? Student 2: Because we cannot see without our sight. Teacher 2: Ok, based on this reason that you gave, I would say that without our hearing we wouldn't be able to hear.	"Ok, based on this reason that you gave, I would say that without our hearing we wouldn't be able to hear"

2	Student: First you see someone and then you hear them. Teacher 2: So how about when I am not facing him and he calls me? Will I first hear him and then see him?	"So how about when I am not facing him and he calls me? Will I first hear him and then see him?"
3	Student: Sight is more important because when we become blind we cannot do anything to be able to see again. Teacher 2: But when I become deaf, can I do something to gain my hearing?	"But when I become deaf, can I do something to regain my hearing?"
4	Teacher 2: Why do we have two eyes and not just one? Student: To be able to see. Teacher 2: Wait, so, wouldn't I be able to see if I had just one? Is there any reason for this? Is there any reason that I have two eyes?	"Wait, so, wouldn't I be able to see if I had just one?"
5	Teacher 2: We could see with just one. Why do I have two? Student: To be able to see far or close. Teacher 2: Can't I see far and close if I close one of my eyes?	"Can't I see far and close if I close one of my eyes?"

4.4 Evaluation of Questions in Year-6 Science Textbooks and Evaluation Booklets

Based on the analysis conducted, the 71 questions located in the students' textbook and evaluation booklet were initially classified in three categories: 55 of them were categorised as "Argumentation" questions, 4 of them as "Descriptive" questions and 12 of them as "Procedural Inquiry" questions. We remind the reader that for the scope of the research, argumentation was regarded as the process of evaluating and justifying claims (Naylor et al., 2007), considering the production both of rhetorical and dialogic arguments.

A supplementary analysis of the 55 "Argumentation" questions that was aimed at examining the scaffolds provided to students, revealed that, in 38 of the questions a picture was given as a scaffold, 24 of the questions provided procedural inquiry guidelines, 12 of the questions provided a model, 6 of the questions provided a table, 5 of the questions provided a description and 2 of the questions provided a graph. 24 of the questions provided a combination of types of scaffolds, 30 of them offered just one type of scaffold, while 1 of them provided no scaffolds to the students. Figure 3 stands as an example of a question providing pictures for supporting students' argumentation efforts.

Additionally, it was revealed that in 23 of the "Argumentation" questions a single claim was given as part of the question and in 3 of them a choice of two claims was given. In total, 26 of the "Argumentation" questions provided a claim to students, this being either a single claim or a choice of two claims. 15 questions did not provide any claim as part of the question, as the claim had to be stated by students during the initial stages of scientific inquiry.

The findings from the analysis of questions located in students' textbooks and evaluation booklets are recorded in Table 4 and in double underlined text in Figures 4.1 and 4.2.

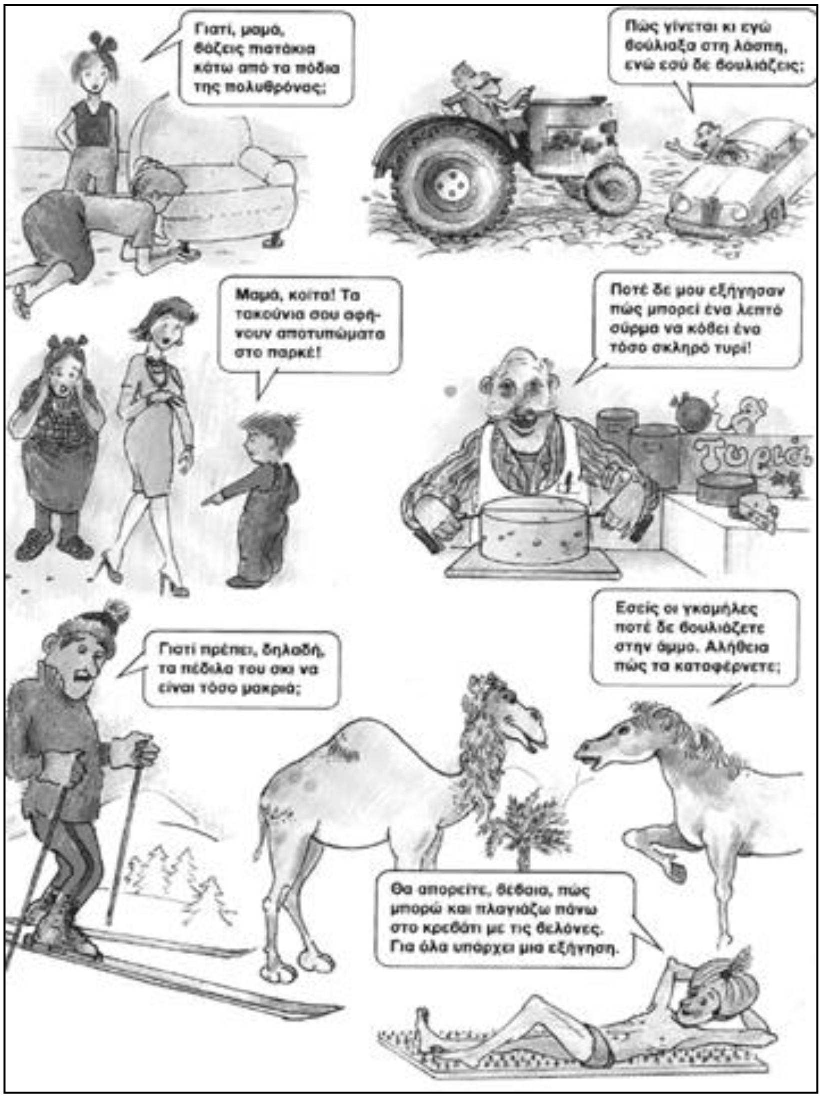


Figure 3. Use of pictures as scaffolds in questions concerning pressure in students' textbook (MOEC, 1997, p.51).

Table 4

Types of Scaffolds Provided in Questions in Students' Textbook

Claim Given		Claim not given	Type of Scaffold					
Single	Two Options		Picture	Procedural Inquiry Guidelines	Model	Table	Description	Graph
23 42%	3 5%	15 27%	38 69%	24 44%	12 22%	6 11%	5 9%	2 4%

Figure 4.1. An account of the activity system of argumentation in science education from students' perspective (central activity).

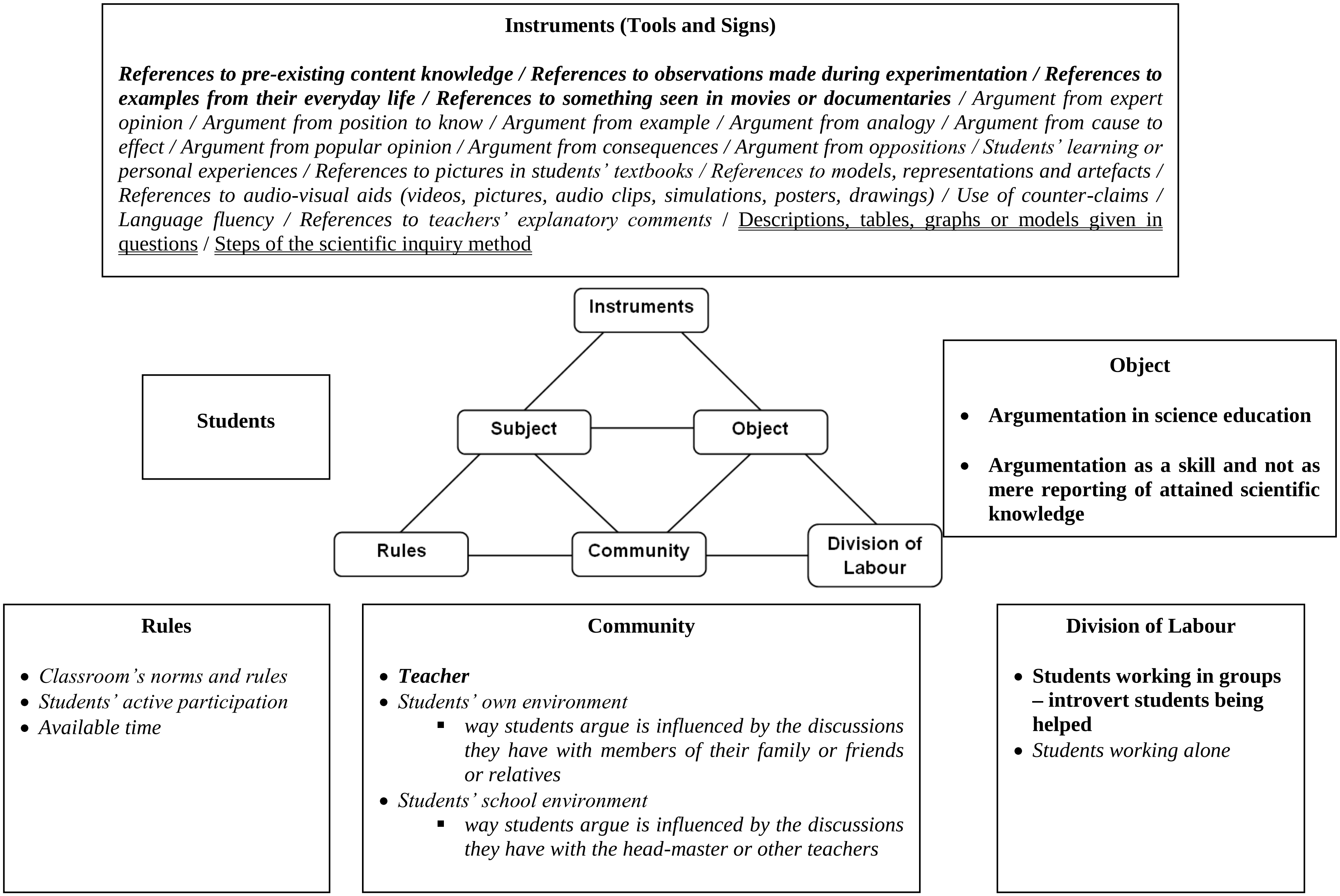


Figure 4.2. An account of the activity system of argumentation in science education from teachers' perspective (neighbour activity).

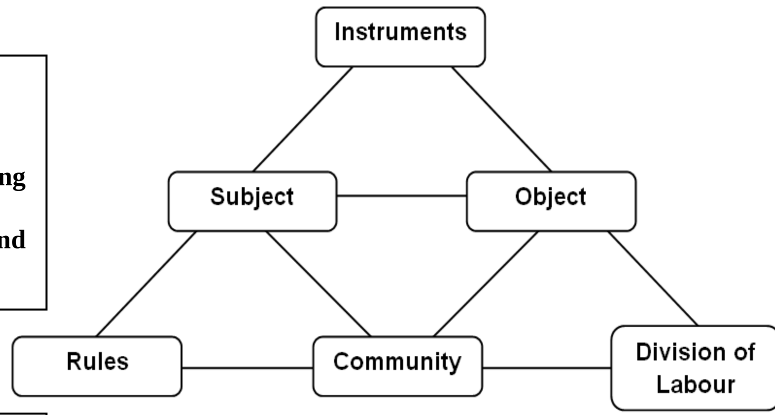
Instruments (Tools and Signs)

Use of argumentation questions / Use of prompts so that students use appropriate terminology or content knowledge / Use of question prompts during discussions / Re-statement of the question / Explicit explanation of what the question asks / Brief reference to experimental results or repetition of the experimental process / Repetition of students' answer / Use of scientific inquiry / Use of counter-claims / Use of supportive utterances (warrants) / Use of observations from experimental work as data or backing

Teachers

Teachers – Personal characteristics

- **be persistent in asking for supporting reasons for a claim given**
- **have the appropriate skills and abilities to facilitate argumentation**



Object

- **Argumentation in science education**
- **Argumentation as a skill and not as mere reporting of attained scientific knowledge**

Rules

- **Teachers should help students acquire the necessary scientific knowledge**
- **Teachers should appropriately design and organise their lessons**
- *Classroom's norms and rules*
- *Available time*
- *Curriculum demands*

4.5 Students' Difficulties with Argumentation: Drawing links between the activity's components

The aim of this section is to reveal the dynamics and interrelations that may exist between the components of the activity system of argumentation or between the different activity systems that were identified. Identifying these, stands as a crucial criterion in supporting the thesis of the paper that argumentation in primary science education can be exhibited as a systemic activity that is more than the sum of the discrete actions that materialise it (Leont'ev, 1978).

The notion of contradictions from CHAT (Engeström, 1987) is used as an analytical tool for this purpose. Students' difficulties with argumentation, as reported by the teachers and the Science inspector in the interviews, were recognised as contradictions. These difficulties were regarded as contradictions and not merely as problems within the activity system of argumentation, since they were regarded as "*historically accumulating structural tensions*" (Engeström, 2005a, p.137) within the system, given that teachers and the Science inspector referred to them not as isolated events but as tensions that were repetitively being experienced by them.

Identified contradictions are graphically presented by using the two activity systems previously constructed: the activity system of argumentation representing the students' perspective, which is our central activity, and the activity system of argumentation representing the teachers' perspective, which is one of our neighbour activities. It should be noted though that, given the definitions of the central and neighbour activities, contradictions identified as existing in the neighbour activity system do affect how actions of the central activity are materialised. For example, if a teacher is struggling to cope with the curriculum's demands, which does not necessarily relate to the central activity, then this may have an effect on how often he facilitates argumentation in his lessons, which is something that will eventually affect what takes place in the central activity.

To begin with, the analysis of the interviews revealed that students face significant difficulties when dealing with argumentation; something to which all teachers and the Science inspector seemed to agree. "*The difficulties they face*", as Teacher 5 highlighted, "*are enormous...and the arguments that they give are not at all sufficient*". Additionally, Teacher 3 stated that students' arguments "*are limited...inadequate...simple"* and that their *"argumentation effort is not organised in an adequate way*".

All teachers reported that one of the main reasons students do not adequately support their claims to build a complete argument is because they have difficulties in expressing themselves or adequately explaining their thinking. As Teacher 2 stated:

> Students don't say the "why" part, they don't bring reasons. They just tell me "yes", "no", "because", "otherwise". And when they tell me the "why" part, they do not explain it in a proper way. Because, in general, they cannot express themselves appropriately, especially in Science, as they come across certain scientific terms they are not aware of. Even with things they know, they cannot express themselves.

Moreover, as Teacher 1 argued, students "*will answer a question you ask them as briefly as possible"* and "r*arely has any student given a complete and sufficient argument"*. Nevertheless, as Teachers 1, 2, 3 and 5 argued, this is not a problem that relates to lack of knowledge but to students' inability to verbally express this knowledge and make the appropriate connections between pieces of knowledge in order to form a complete argument:

> First of all, my students have a problem of expressing themselves. What I mean is that they might know the answer but they cannot express it. Secondly, their thinking is too naïve; they do not get involved in a process to link together the elements they know to reason about something (Teacher 3).

Concerning the reported inability to make connections, Teacher 1 gave a specific example from her teaching:

> They aren't using what they learn. Soil contains air. When they had to use this, they couldn't easily use it to say that it is because soil contains air that...they couldn't use this to provide an argument for one of the examples I gave them. And it was easy. Therefore, it is the mechanism they did not have, the mechanism of reasoning; that they had to connect these all together. They have a difficulty in being able to connect their data in order to complete a thought in order to reason.

The Science inspector and Teacher 6 seemed to disagree with this view, as they argued that content knowledge is crucial for a student to be able to build a solid and sufficient argument: "*to be able to reason, you have to support it on something you have learnt before. If you do not base it on something, then it means that you speak carelessly just for the sake of reasoning*" (Science inspector).

The first difficulty that students face, identified by the participants as a difficulty to express themselves in order to build sufficient arguments, may depict a tension that exists between students' verbal abilities and either their own motive to engage in argumentation or their teachers' expectations for them to engage in argumentation. Additionally, the reported difficulty that students face in making connections between pieces of content knowledge and expressing a complete argument, may be an indication of a conflict that exists between (a) their ability to make connections or their ability to use content knowledge as a tool, again in respect to the teachers' expectation that you have to make these connections or use content knowledge in order to create an adequate argument, and (b) students' own motive to engage with argumentation. Both conflict states represent the first contradiction that exists between the components of the subject, the instruments, the rules and the object in the activity system of argumentation, illustrated as Contradiction 1 in Figure 5.

Another difficulty that students seem to face with argumentation, and to which all teachers referred, is the problem of language or speech. The fact that a dialect of Greek is used in Cyprus in spoken conversations and not formal Greek, seems to be creating some problems for students who often find it difficult to fluently express themselves in Greek which is the official spoken and written language in schools. "*Personally, I think that the Cypriot dialect poses a lot of difficulties*", as Teacher 3 emphasised. Teacher 1 stressed that this is a difficulty that students face not only in science education but in other school disciplines as well. This, as she explained, creates difficulties during students' argumentation efforts: "*And when you have this speech problem in other disciplines as well, it is more obvious in Science when you have to express very logical thoughts and answer difficult questions*". Based on her teaching experience, Teacher 2 shared the same thoughts on this matter and she referred to an example when, in order to help her students overcome the language problem and the difficult terminology in electricity, she first had to help them to become familiar with the scientific terms:

> In Science, they come across scientific terms that they don't know. We first had to name the lamp, the metal part of the lamp, that this is an insulator, this is a conductor, this is the glass part, like this. I was helping them a bit to be able to familiarise with these. I think in Science you have to explain the terms from the beginning. At first, I let them express themselves, just to see what they understood, but we couldn't communicate. And when I asked them how they connected those, they told me that we put the one wire on the one side of the battery. "Which side?", I asked. This is what I mean; they couldn't say this, they couldn't say that we put it on the positive pole, on the negative pole, on the metal part. You have to explain these from the beginning to communicate with them.

This second difficulty that students face, related to language or speech and the effort that students make to deal with the particular scientific terminology, may represent a conflict between students' willingness to engage with argumentation, their verbal ability based on the fact that they use the Cypriot dialect in their spoken conversations and the expectation that exists that they must communicate in formal Greek in speaking and in writing. Therefore, this seems to represent a contradiction between the components of the subject, the instruments, the rules and the object of the activity system of argumentation, graphically depicted as Contradiction 2 in Figure 5.

Further, the Science inspector made a special reference to the teachers' role, claiming that many teachers do not use appropriate methods to help students develop their argumentation skills, that is "t*he method that should be used so that students can discuss in a dialogic way with other classmates*". This, as the Science inspector reported, may be due to the insufficiency of time and teachers' heavy teaching workload:

> From what I can see, teachers have a really heavy workload and therefore, because of their effort to cover this, they cannot give the needed attention on developing certain skills. Teachers try to cover what they have to in 80 minutes and there is no time to develop this particular skill.

The above claim concerning the teachers' role and the methods they apply to implement argumentation, may be indicative of a tension that exists between the teachers' willingness to practice argumentation through the use of appropriate methods and their need to cope with the curriculum demands. This seems to depict a contradiction that exists in the activity system of argumentation between the components of the instruments, the rules, the subject and the object, represented as Contradiction 3 in Figure 6.

Furthermore, Teacher 5 made a particular reference to the nature of the lesson, and more specifically to the fragmented character of the scientific processes being followed, which seems to hinder students' argumentation efforts:

> I think there is a problem with the nature of the lesson. It doesn't give students the opportunity to realise more clearly the picture, the bigger picture. Because it focuses on this activity, then on the other activity, students cannot understand how each event is connected to the other and to something bigger maybe; to be able to build a mental construction inside their minds; to see how the different pieces of the puzzle link together, to put them together and reach a conclusion and reason about this conclusion. When we just tell them, do this thing [an experiment], what is the conclusion here? Do the other thing, which is similar to the previous thing, what is the conclusion here, which are the same basically, what scientific reasoning should you expect?

Teacher 5 also criticised the fact that the teachers' textbook suggests typical answers that should be expected from students in each activity; something that may reveal the official policy concerning argumentation in primary science education and may also have an effect on the way teachers may or may not promote argumentation, as he claimed.

The difficulty Teacher 5 referred to may indicate a contradiction between the motive or the willingness to promote argumentation and again, the motive to cope with the curriculum demands: to follow the guidelines suggested by the teachers' textbook, and that students should complete the proposed textbook activities. This could be defined as a contradiction between the object, the subject and the rules of the activity system of argumentation, graphically depicted as Contradiction 4 in Figure 6.

Another reason that may have an influence on how students express themselves, suggested by Teacher 3, is the role of the family and whether children have learnt to express themselves when interacting with their family or not. As he stated: "*I believe that this comes from the family as well, because students that are used to communicating with their parents with a single yes or no, express themselves likewise in the classroom and don't expand on what they say*".

What Teacher 3 referred to, can be read as an indication of a tension, that the students' family may have an influence on their argumentation skills. It reveals thus a possible contradiction that may exist between the components of the subject, the object and the community, expressed through the influence of the students' family. The contradiction is portrayed as Contradiction 5 in Figure 5.

Finally, the Science inspector and Teacher 5 referred to the limited interest shown by students concerning argumentation. As the Science inspector said, "*many times I see that the arguments they give are given carelessly and without serious thinking that makes you realise that they don't take this seriously*". Concerning the reasons for this, the Science inspector argued that "*probably both the pedagogy concerning this skill and the lessons that should have preceded were not appropriate in order to help students realise the importance of this skill*".

This final difficulty reported, may depict a contradiction between the rules, the subject and the object of the activity system of argumentation that students' personal interest may have an influence on the way they engage with argumentation in respect to the expectation that exists that students should depict some interest in engaging with argumentation. The contradiction is illustrated as Contradiction 6 in Figure 5.

5. Conclusion

This paper illustrates how argumentation can be exhibited as a systemic whole, involving interconnected instruments, rules and social practices. This has been implicitly recognised in the literature (e.g., Jiménez-Aleixandre, 2008; Kelly, 2008) but the description of argumentation as a systemic activity and especially the often contradictory dynamics and interrelations that may exist between its separate components has not been adequately shown or examined until now. This paper contributes towards this effort by using appropriate theoretical, methodological and analytical tools from Cultural-Historical Activity Theory in order to study the teaching and learning practices through which argumentation is facilitated in science education in primary schools in Cyprus (see Figures 4.1, 4.2, 5 and 6). We emphasise, both for teachers and researchers, the systemic character of the activity of argumentation that cannot be adequately realised or explained only by noticing the discrete actions that take place, as the activity is more than the sum of its discrete actions (Leont'ev, 1978). Only by examining argumentation in its totality and the tensions that exist within and between the elements that comprise it, can we understand what further actions need to be taken in order to support its facilitation in practice.

Figure 5. Contradictions identified in the activity system of argumentation in science education (central activity - students' perspective).

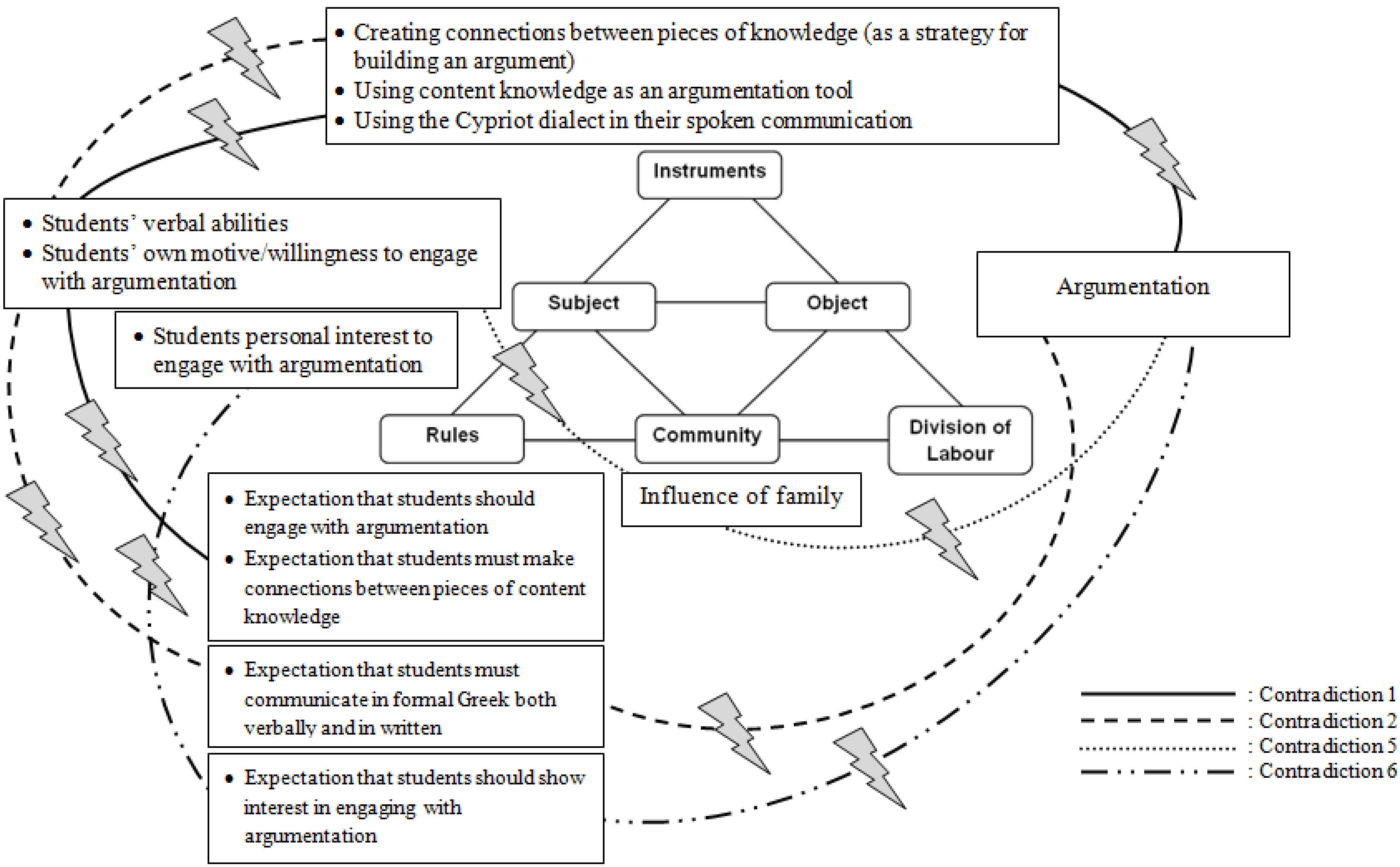
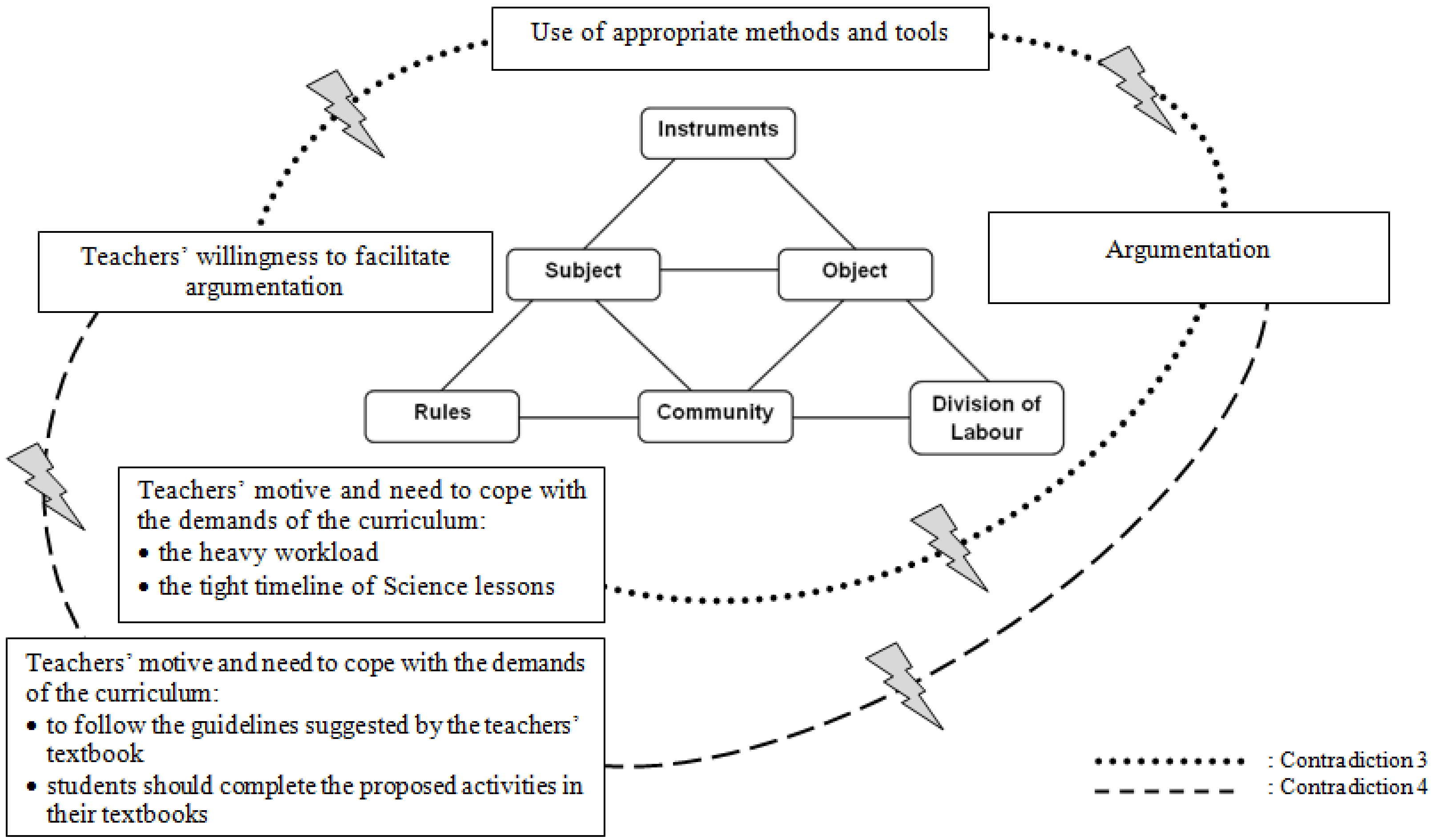


Figure 6. Contradictions identified in the activity system of argumentation in science education (neighbour activity - teachers' perspective).



Acknowledgements. The first author would like to thank Professor Yrjö Engeström and people at the "Center for Research on Activity, Development and Learning" (CRADLE) for their invaluable feedback given concerning the paper, during the author's visit at the center. Also, the first author would like to thank all the teachers who participated in the research, without whom the project would not have come into life.

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Figures

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Tables

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