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'Scaffolding' through talk in groupwork learning

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ABSTRACT

In the present study, we develop and deploy a conceptual framework of "scaffolding" in groupwork learning, through the analysis of the pursuit of a learning goal over time. The analysis follows individuals' different experiences of an interaction as well as collective experiences, considering individual attainment as a result of a bi-directional contextualized conversation and action. We detect, describe and evaluate two (2) types of interaction that can be characterized as "scaffolding process": the first concerns "Scaffolding individual thinking" and the second "Scaffolding collective thinking". The latter, apart from presenting the educational advantages of collective thinking through peer discussion (D) and curriculum-focused evaluation context of Teacher Initiation – Student Response – Teacher Follow up (IRF), also presents the advantage of 'spiral' verbal exchanges in which the teacher "tunes in" to the students' present state of ability or understanding (spiral IDRF).

1. Introduction

The notion of "scaffolding" was developed in the context of dyadic interaction between a parent and their very young child or between an adult and a very young child (Bruner, 1983, 1985; Wood, Bruner, & Ross, 1976)—a context that quite differs from the school context in the way that "discourse between a teacher and an individual pupil is usually contextualized by other discourse, whereby the pupil relates to the teacher as part of a group or whole class" (Maybin, Mercer, & Stierer, 1992, p. 188). While the metaphor of scaffolding is tremendously appealing in principle (Maybin et al., 1992, p. 187), indiscriminate usage of the term in educational research so as to describe any teaching intervention has almost rendered it meaningless (Scott, 1998). In acknowledgement of this lack of clarity, there have been attempts to set criteria (Maybin et al., 1992) and develop an appropriate definition of scaffolding in school context (Mercer, 1995, pp. 72–77; Scott, 1998; Mercer, 1998; Wegerif, Mercer, & Rojas-Drummond, 1999).

As IRF exchanges, i.e. Teacher Initiation – Student Response – Teacher Follow up (Lemke, 1990; Mehan, 1979; Sinclair & Coulthard, 1975) could be associated with more than one pedagogic function (Kovalainen & Kumpulainen, 2005; Rojas-Drummond & Mercer, 2003; Wells, 1995), Mercer, Wegerif and Rojas-Drummond (Mercer, 1998; Wegerif et al., 1999) along with Dawes (2004) suggest that IRF sequences might constitute scaffolding in whole classes or small groups. So long as the teacher's follow up (F) taps into responses or initiations originated from students (R) in order to create a new learning cycle and thus a spiral IRF sequence towards the attainment of a learning goal, we can conceptualize IRF verbal exchanges as a way to "scaffold" learning in school context (Mercer, 1998; Oh, 2005; Wegerif et al., 1999).

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Apart from whole classroom teacher-led activities, classroom activities often involve small group work with the teacher coaching, guiding or monitoring the small group activity (Hoek & Seegers, 2005; Howe, Tolmie, Duchak-Tanner, & Rattray, 2000; Mercer, Dawes, Wegerif, & Sams, 2004a; Rasku-Puttonen, Eteläpelto, Häkkinen, & Arvaja, 2002). Since teachers' discursive actions are a very important and complex component of collaborative learning (Mercer et al., 2004a; Rasku-Puttonen et al., 2002), the discourse analysis in groupwork learning is useful to take into account the IRF exchanges between the teacher and the students of the peer group. More importantly, though, it needs to consider the development of collective thinking in the peer discussion among students, as symmetrical relations provide more opportunities for thinking together (Mercer, 2000; Mercer et al., 2004a; Wegerif, 2004). To our knowledge, there is no study in school context that has developed an operational definition of "scaffolding" based (a) on the verbal exchange IRF and at the same time (b) on the prospect of collective thinking (Mercer, 2000) in peer discussion among students.

Taking into account these important features of classroom interaction, the present study attempts to introduce a framework for the analysis of scaffolding through talk in groupwork learning, addressing the lack of clarity in the way 'scaffolding' is operationally defined in classroom groupwork learning. "Scaffolding" is approached as a teaching-and-learning process – aiming at the individual learning performance of each student that participates – and not unilaterally as a teaching intervention or a form of 'help' given by the teacher (see the approach of Maybin et al., 1992). Thus, we consider "scaffolding" as a "bi-directional interaction" aiming at individual attainment and not merely as a teaching intervention (see also Reid, 1998).

In the area of computer science teaching, increasing emphasis is being placed on the value of collaborative work for the production outcome. However, little evidence, beyond subjective satisfaction (and in some cases general test performance), has been provided in terms of learning outcomes (Holmboe & Scott, 2005). Thus, the study in hand attempts to develop and apply a sociocultural framework for investigating the process of scaffolding individual attainment in computer science curriculum.

The use of artefacts is supposed to transform the cognitive and communicative requirements of human activities and the way in which the collaborative action is organised (Crook, 1994; Saljo, 1998). In an evening vocational technical school in Greece, we utilise two (2) different learning environments (educational software environment, paper and pencil environment) to pursue computer science curriculum. We attempt to seek associations among learning environments, types of scaffolding processes and independent individual attainment. Those kinds of studies are reported to be useful and necessary in order to explore the context-dependent nature of scaffolding in school contexts (Hoek & Seegers, 2005; Kovalainen & Kumpulainen, 2005; Mercer, 2000; Mercer & Fisher, 1997).

Thus, the research in question aims at developing, deploying and applying a conceptual framework of "scaffolding" in groupwork computer science learning and therefore provides answers to the following research questions:

a. How is 'scaffolding' manifested during the particular groupwork computer science learning activities?
b. Are there any associations between types of scaffolding processes and independent individual attainment in the two learning environments?

In this paper, we first examine the notions of spiral IRF exchanges as a way to scaffold through talk and of collective thinking as it may emerge in peer discussion in a groupwork context. Then, we go on to present the setting and the research method of the study itself, followed by its relevant findings. We conclude the study by discussing the significance of the framework we developed, the educational importance of the scaffolding patterns, limitations and future plans.

2. Theoretical framework

2.1. 'Spiral' IRF a way to 'scaffold' through talk

"Scaffolding" is defined as the teaching-and-learning process, wherein the adult sets mental "scaffolds" through talk, offering a "vicarious form of consciousness" (Bruner, 1985), in order for the child to be able to move into his/her Zone of Proximal Development (ZPD) (Vygotsky, 1978) and advance from the dependent competence to the independent competence. This process continues with the adult gradually withdrawing the mental "scaffolds" as the child presents an increasing independent competence (Bruner, 1983) and finishes when the child is capable to do on their own what, up to that point, was possible only with the help of the adult. Tharp and Gallimore (1988) referred to "scaffolding" as the – responsive to child's performance – adult assistance that helps the child progress from assisted performance to unassisted performance.

In a school context, the criteria to discriminate between any kind of teacher intervention helping a learner to accomplish a task and a "scaffolding" intervention are developed thoroughly by Maybin et al. (1992). According to their study, a teaching intervention or "help" can be characterized as "scaffolding" if:

1. There is some evidence of a teacher wishing to enable a student to develop a specific skill, grasp a particular concept or achieve a particular level of understanding. "Scaffolding" is help given in a specific learning activity, which has finite goals.
2. It is "help" which will enable students to achieve a learning goal which they would not have been quite able to achieve on their own.

3. It is "help" which is intended to bring students closer to a state of competence which will enable them eventually to provide evidence of independently achieving the learning goal.
4. There is evidence, usually in the quality of talk, that the teacher is 'tuned in' to the student's present state of ability or understanding.
5. There is some evidence of a student successfully achieving the learning goal with the teacher's help.
6. There is some evidence of a student having achieved some greater level of independent competence as a result of the scaffolding experience, namely, demonstrating his or her increased competence or improved level of understanding in dealing independently with some subsequent problem.

If we assume having a teaching-and-learning process which meets the 1st, 2nd, 3rd and 5th of the above mentioned criteria – without being able to meet the 6th criterion which presupposes a "subsequent problem" – which is the way to acquire some evidence of meeting the 4th criterion as well? Namely, which is the way to acquire some evidence in talk of a teacher being 'tuned in' and responsive to the student's present state of ability or understanding? (see also Maybin et al., 1992; Scott, 1998; Tharp & Gallimore, 1988).

Wells (1995) argues that the Feedback/Follow up (F) offered by the teacher in an IRF verbal exchange, otherwise mentioned as triadic dialogue (Lemke, 1990), has an increased educational value if it is not simply an evaluation of a student's response (see also Initiation-Response-Evaluation scheme mentioned by Mehan, 1979) but rather a start of a new subsequent teaching and learning cycle. Following the same train of thought, Mercer and his colleagues (Mercer, 1998; Wegerif et al., 1999), observing and studying teaching-and-learning activities in Mexico schools, detected some different ways in which teachers had used IRF sequences in educational discourse. They reported that the teacher's Follow up[2] was likely to be a new initiation, question or prompt by the teacher. Thus, they observed that in certain successful cases, verbal exchanges of IRF type exist as units of a more complex and interconnected structure "I-R_1-F_1-R_2-F_2-." (Spiral IRF).

The Spiral IRF sequence is structurally and essentially different from a pattern of discourse in which IRF verbal exchanges constitute independent and self-contained modules "I_1-R_1-F_1- > I_2-R_2-F_2- > . . ." ('Loop' IRF sequences).

In Spiral IRF sequences, the teacher taps into responses or initiations originated from students in order to make his/her new initiation with the aim of creating continuity and context (Edwards & Mercer, 1987), thus guiding students to solve the problem. The teacher uses initiations and follow-ups not only to evaluate but also to guide the learning process. He/she uses questions, prompts, cues, clues, reformulations, elaborations, recaps, confirmations and he/she models thinking strategies not only to focus on certain knowledge objects but also to maintain students' attention to a continuous train of thought and construction of new understanding (Joiner, Littleton, Faulkner, & Miell, 2000; Mercer, 1998, 2000; Murphy, 2008; Rasku-Puttonen et al., 2002). In this way, the teacher utilizes sequences of contingent interconnected initiations, responses and follow-ups to create continuity and co-construct meaning with their students. Therefore, the IRF verbal exchanges constitute a greater spiral "chain" of verbal exchanges between the teacher and the students.

On the contrary, the 'loop' IRF exchanges function "as discrete tests of understanding or retention of given knowledge" (Mercer, 1998, p. 89).

2.2. Collective thinking through talk in groupwork learning

At the same time, in groupwork learning it is probable that the students generate a peer discussion or even debate to reach a consensus about a problem posed by an expert (teacher, educational software) (Howe et al., 2000; Mercer et al., 2004a; Wegerif, 2004). In this way, the development of collective thinking (Mercer, 2000) is likely to occur in the peer discussion among students.

Mercer (2000) introduced the notion of collective thinking to describe talk in a joint problem solving activity where participants share relevant past experience and information creating context for the joint activity and work with each other's ideas in order to use language as a tool to transform the given information into new understanding. In particular, "exploratory talk is an effective way of using language to think collectively" (Mercer, 2000, p. 153) and cumulative talk "can be very usefully applied for getting joint work completed" with participants "using language to think together" (Mercer, 2000, pp. 31–32).

Exploratory talk is the kind of talk in which partners engage critically but constructively with each other's ideas. Statements and suggestions are offered for joint consideration. These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered (Mercer, 2000).

Cumulative talk is the kind of talk in which "speakers build on each other's contributions, add information of their own and in a mutually supportive, uncritical way construct shared knowledge and understanding" (Mercer, 2000, p. 31).

As Mercer (1995, p. 104) has pointed out 'exploratory', 'cumulative' and 'disputational' are not meant to be descriptive categories into which all observed speech can be neatly and separately coded. They are analytic categories, typifications of ways in which students have been observed to talk together. In practice, excerpts of cumulative talk are likely to be part of

[2] Henceforth, we refer to the Feedback/Follow up part as Follow up, for it is a blanket term comprising cases when a Follow up may be a new initiation, question or prompt.

a more extended exploratory talk episode. However, there are also cases in which cumulative talk is neither integrated into more extended episodes of exploratory talk nor evolved into exploratory talk.

3. Method

3.1. Research design

The study was conducted into three stages: diagnostic pre-test, teaching-and-learning groupwork intervention and evaluation post-test in an environment as authentic as possible. The tasks as well as the diagnostic and evaluation tests assigned to students were integrated into their school "computer science" courses, as the classroom teacher of the corresponding curriculum courses was one of the researchers. The dual role of teacher-researcher helped to categorize and interpret the data with greater validity since "knowing a school culture from the inside allows researchers to appropriate participants' competence systems and so enables a richer interpretation of observed language and events" (Roth, 2001 reported on Mercer, 2008, p. 56). Thus, the kind of intervention is rather a teacher's intervention integrated into students' everyday classroom life and not an intervention by an external researcher.

It is also true that "Computer Science" in Greek secondary education is mainly taught in vocational schools. Therefore, we selected an evening vocational technical school to study the pursuit of computer science curriculum in secondary education.

Aiming at identifying types of scaffolding processes we applied a descriptive analysis. However, as there is the limitation of lack of evidence of 'individual independent competence' in naturalistic/observational research (Mercer & Fisher, 1997), we also developed a coding scheme and applied a comparative analysis. Our aim was to find out an association between types of scaffolding processes and individual attainment across the different learning situations of the study. To that end, the teacher-researcher used diagnostic and evaluation tests before and after the groupwork activities that pursued the learning goals assessed by the tests.

3.2. Participants

3.2.1. Students

Six (6) groups of students of a Greek evening vocational technical upper secondary school (four dyads and two triads) participated in the study along with their teacher-researcher of the "Computer Hardware" and "Basic Maths in Computer Science" curricular subjects. The 14 students, 9 males and 5 females, were first-year students aged from 17 to 30 with average age 23.4 years. Greek vocational technical education "has been generally viewed as an unpleasant alternative, useful only to the "failures" of second-level education" (Patiniotis & Stavroulakis, 1997). Greek evening upper secondary schools, as the one that participated in the study, belong to non-compulsory formal education and are attended exclusively by working or unemployed students. Thus, it is the students' own choice to attend the school in order to develop a "Computer Science" vocational background and/or get an upper secondary (Lyceum) school leaving certificate. The students who participated in the study were not working in "Computer science" jobs at the time of the data collection. Therefore, we can say that the students of the study had low to moderate learning capacities, probably already established ways of learning, no time for much homework but also a clear goal about why they attended school courses (cf. Rogers, 2002). The students had almost no experience of educational software tasks (a 10-min familiarization with the software before the main activities of the study in hand). They had some experience of general application software tasks (wordprocessors, etc.) and they knew each other, as they worked in the same small group in the computer lab.

3.2.2. Teacher

The classroom teacher can be described as a "Computer Science" teacher who – at the time of the data collection – had already had 8 years of teaching experience and had been continually developing his professional competence by studying and researching educational sciences. What is more, his pedagogical thinking had been influenced by the neo-vygotskian approaches to learning (e.g. Crook, 1994; Mercer, 2000; Wegerif, 2004).

During the activities, the teacher tried to use Spiral IRF sequences to scaffold students' performance until the students solved the problem with his help (see Section 2.1 in this paper and also Mercer, 1998; Oh, 2005; Wegerif et al., 1999). He also told students that, doing the activities, they had to cooperate and talk to each other in order to reach a consensus. He stimulated discussion about elements of the solution process, avoiding direct answers. Instead, he invited students to come up with their own solutions and redirected their individual answers to the group (see also Hoek & Seegers, 2005).

Seeking evidence of students' assisted performance within the duration of two uninterrupted teaching hours (2× 35 min in Greek evening schools), he set low to moderate learning goals[3] and he intervened to instigate peer discussion whenever it was not developed. He acted this way, in order to elicit problem-solving contributions on behalf of the students towards knowledge construction and problem solution. In most of activities, he generally succeeded in having the students provide evidence of assisted performance within 35–60 min.

[3] Representative samples of learning goals are cited in Appendix.

3.3. Greek educational context

The Greek secondary education policy focuses mainly on higher education entry examinations (Siminou, 2007) and less on educational processes. In classrooms, groupwork and especially cooperative and collaborative learning are limited. This is due to the lack of a substantial initial and in-service teacher training which takes into consideration teachers' professional needs and beliefs (Gravani & John, 2005; Karavas-Doukas, 1996). Yet, ICT courses in computer labs brought in the task-oriented and project-oriented learning as well as the setting of dyads and triads working together on a computer screen (Panselinas, 2002). However, due to top-down imposed policy decisions in ICT integration in schools and lack of an appropriate teacher training system that meet teachers' needs and takes into account both classroom culture and educational theory and research, teacher-centered pedagogy practically prevails (Jimoyiannis & Komis, 2007). Therefore, Greek teachers are not trained in ways to evolve a groupwork activity into a collaborative learning activity, whereas the teacher coaches students' "thinking together" (see Mercer et al., 2004a).

Thus, the students of the research in question had got used not to talking to each other while learning with the presence of a teacher but rather addressing the teacher whenever prompted to give an answer, set an hypothesis, draw a conclusion or generally contribute to the discussion. In this way, the teacher's prompts to "talk to each other" were actually prompts to adopt a communication behaviour they were not familiar with, at least when the teacher was present.

3.4. Learning situations

3.4.1. Learning goals of learning activities and written tests

The groupwork activities/tasks organized by the teacher–researcher as a teaching-and-learning intervention were integrated in students' courses: "Computer Hardware" and "Basic Maths in Computer Science" and had certain learning goals derived from the curricula (ΥΡΕΡΤΗ/ΥΠΕΠΘ, 1999a, 1999b). We tried to arrange the level of tasks and their corresponding learning goals so as to fit students' capacities and already acquired knowledge. We also took into account that students had to solve each problem, provide evidence of grasping a concept or achieving a particular level of understanding, with the help of the teacher, within two uninterrupted teaching hours (70 min).

The learning goals in "Basic Maths in Computer Science" activity concerned the construction of understanding of some properties of Numeral systems as well as the exercise of the skill to convert a number's decimal representation into its corresponding binary representation and vice versa. The learning goals in "Computer Hardware" activity concerned the construction of understanding of the computer processor features and the development of the ability to make predictions regarding the relation between those features and the performance of the processor.

Those learning goals were described in terms of students' competence to respond correctly to the corresponding questions of individually handed-out written tests. Some of these goals with their corresponding test questions are cited in Appendix. We used questions in written tests to assess the achievement of the learning goals due to the nature of the particular learning goals, the provision of evidence of independent individual competence (6th criterion of Maybin et al., 1992) and also because it is the main way of assessment at least in European education systems (Eurydice, 2009). The written tests administered to the students before (pre-test) and after (post-test) the teaching-and-learning activities were the same. Only in cases that the learning goal concerned "drill and practice" exercises,[4] we had different numbers in pre- and post-tests.

3.4.2. Learning activities in different learning environments

The activities of the study took place in four (4) different groupwork learning situations: "Computer Hardware learning in the educational software environment of ModelsCreator", "Computer Hardware learning in paper and pencil environment", "Numeral systems in the educational software environment of DELYS" and "Numeral systems in paper and pencil environment".

3.4.2.1. Educational software environments. DELYS consists of a collection of complementary microworlds regarding different subjects of Computer Science (Dagdilelis, Evangelidis, Saratzemi, Efopoulos, & Zagouras, 2003). In the present research, the microworld of "virtual scale" is used (Fig. 1). It is a virtual laboratory that was designed for students to understand the relationship between the decimal and the binary numeral systems and to investigate basic principles of various numeral systems. The user interface of the software contains a pair of scales where the users can put weights on its left tray representing the numeral weight units of the decimal system (1, 10, 100, etc.) and weights on its right tray representing the numeral weight units of the binary system (1, 2, 4, 8, etc.). The scales balance when the user is "unlocking" the system and the represented numbers on the left and right trays have the same "weight". At the same time, apart from the representation using weights for the binary and decimal systems, there is also a representation with digits, for example 12 in the decimal system or 1100 in the binary as it is shown in Fig. 1. The students are able, using the software, to change any of the two representations and the software changes the other representation automatically.

"ModelsCreator" is a computer-modeling environment that allows students to create and test models representing different aspects and phenomena of the natural world (Fig. 2). Testing models' behaviour is carried out by direct manipulation

[4] Tests concerning "Processor"– Question 1(a) and Tests concerning "Numeral systems"– Question 2.

Fig. 1. The interface of DELYS (virtual scale).

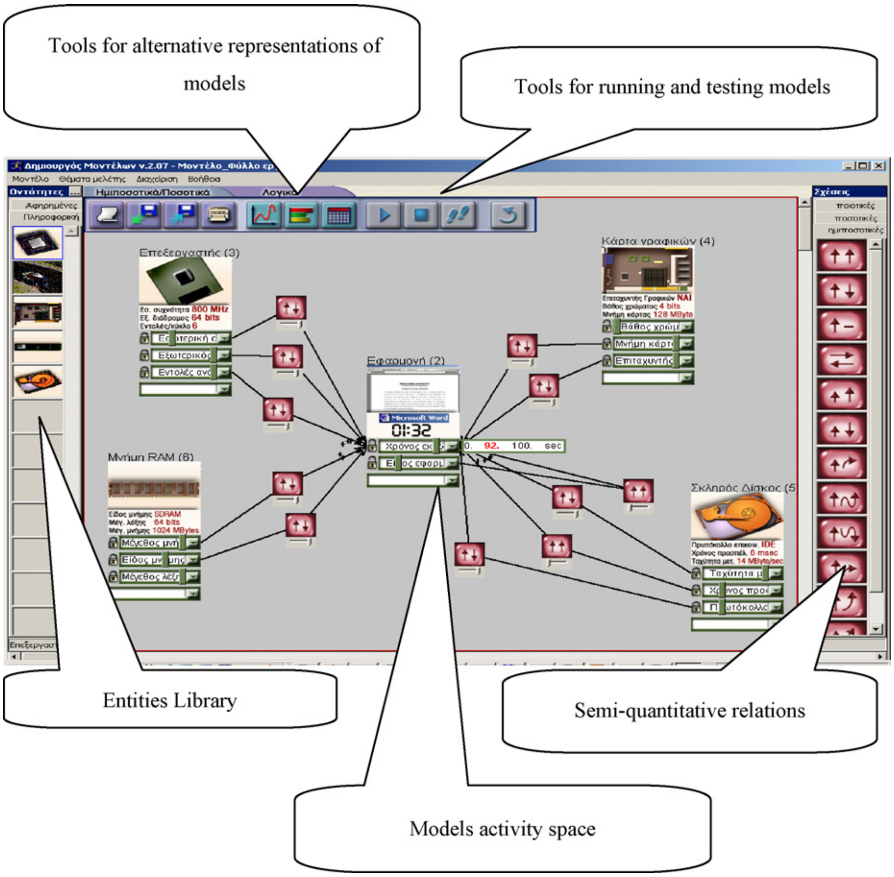

Fig. 2. The interface of ModelsCreator.

and on the basis of the multiple representations available within the environment of ModelsCreator (simulation, bar charts, graphs, tables, etc.) (Dimitracopoulou & Komis, 2005). “ModelsCreator” contains objects that have a mediating role helping students to manipulate abstract entities and concepts (properties of objects). Properties of the same entity or other entities can be connected with qualitative, semi-quantitative or quantitative relations. “ModelsCreator” integrates semi-quantitative models, which meet the requirements of many curriculum subjects, permitting interdisciplinary use of the modeling process. The educational scenario we designed, deployed and tested concerns teaching-and-learning of Hardware concepts (Panselinas et al., 2005).

The activities were based on worksheets. Parts of them are cited in Appendix. ModelsCreator educational software environment allowed us to organize inquiry modeling activities (see ‘Computer hardware’ worksheet) to pursue inquiry learning suggested to offer a scientific and authentic way of doing and learning science (Lohner, van Joolingen, Savelsbergh, & van Hout-Wolters, 2005). Both DELYS and ModelsCreator environments gave us the opportunity to organize hypothesis testing activities/tasks that “have been promoted as a powerful context for supporting knowledge acquisition in science (Howe et al., 2000, p. 262). For example, in DELYS sub-task 2, there is a problem and the students are prompted to reach a consensus through discussion. This discussion may lead them to set and test their own hypotheses through a virtual experiment that provides them with meaningful feedback. Finally, students and teacher discuss the outcome of the experiment and the processes they followed to draw conclusions. In ‘Computer hardware’ task in ModelsCreator, students are prompted to create a model and thus set a hypothesis about the relation between ‘processor internal frequency’ and ‘software execution time’. Students test the model and receive teacher-expert guidance in the “Let’s think” phase (see Appendix). Finally, the students have the opportunity to integrate their new ideas, to change and re-test the model. On the ‘Numeral Systems’ worksheet there are also sub-tasks (Sub-task 1), which set problems and questions required to be answered by the students collaboratively, while the software offers appropriate feedback (digital representation and balancing of the scales) (see Panselinas & Komis, submitted for publication). Thus, the sub-tasks create a computer-based learning context appropriate for supporting students’ “thinking together” (see also Wegerif, 2004).

3.4.2.2. Paper and pencil environment. In the paper and pencil environment, the group of students and the teacher were sitting around a school desk in the computer lab. The only tool/artefact each student and the teacher used was the educational scenario, a blank paper and a pencil. According to the scenario for Numeral system activity a) students had to convert the decimal representation of a number into its corresponding binary representation and vice versa with the help of the teacher and b) teacher had to led a dialogue about answering questions like those posed in Sub-task 2 (‘Numeral systems’ worksheet). The educational scenario for Computer hardware activity consisted of a teacher-led dialogue based on the “Let’s think” text of ‘Computer hardware’ worksheet (part of it in Appendix).

3.5. Procedure and data collection

The two diagnostic pre-tests were administered to all first-year “Computer Science” students of the school (22 students). By the time of the data collection the 22 students were members of 10 peer groups (8 dyads and 2 triads) working in computer labs. The formation of the peer groups had been the students’ responsibility in the beginning of the school year. Due to micro-level discourse analysis we were going to apply and the number of learning situations we were going to study, we selected six (6) groups for the study: three (3) for the educational software environment and three (3) for the paper and pencil environment. Based on the data provided by the diagnostic tests, we selected the groups in a way that, comparing the two learning environments, we had in each of them students with equal capacities and already acquired knowledge. We worked like this because we wanted to compare the two learning environments in terms of association between types of scaffolding processes and individual attainment. All the groups that participated in the study consisted of students with similar ages (peer groups).

The two diagnostic pre-tests were administered on Friday during the class hours of “Computer Hardware” and “Basic Maths in Computer Science” courses.

The six (6) ‘Numeral systems’ activities (3 groups in DELYS environment and the other 3 groups in paper and pencil environment) took place on Tuesday starting from 16:00 in the afternoon until 22:30 in the evening. Next day, same time, we had the six (6) ‘Computer Hardware’ activities (3 groups in ModelsCreator environment and the other 3 groups in paper and pencil environment). The three (3) groups of students (two dyads and one triad) worked in the two educational software environments at a stand-alone computer in the computer laboratory with only the teacher present and not the other two groups. The other three (3) groups used only paper and pencil, while the rest of their schoolmates were attending a different course in a different classroom. The twelve (12) activities were captured on video so as to capture not only verbal but also non-verbal interaction and activity. The discourse of the participants was recorded on annotated transcripts.

The next Friday, during the class hours of “Computer Hardware” and “Basic Maths in Computer Science” courses, the two evaluation post-tests were administered to students that participated in the study.

Once during the week of intervention and once after the intervention, we informally interviewed the students-participants in order to find out whether they undertook by themselves any related additional learning activities aside from the research activities and tests. We detected two students that involved in such additional activities and we excluded their data from the analysis. They were excluded because we wanted to associate any change in academic

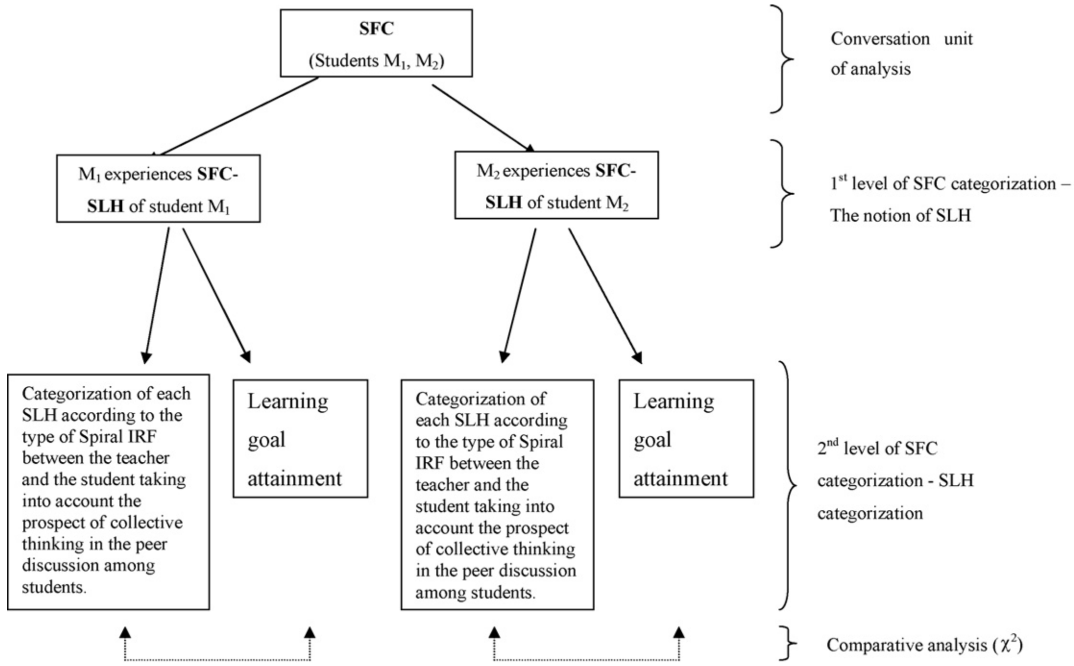

Fig. 3. The method of analysis.

performance demonstrated in responses to evaluation pos-test questions with what happened in teaching-and-learning activities.

3.6. *Method of analysis*

We developed and deployed a computer-based discourse analysis, in a way that after the analysis of teaching-and-learning activities, we came up with episodes of talk and action (qualitative data).

We created and used as unit of analysis of the educational conversation the notion of "Short Focused Conversation" (SFC) (Fig. 3, conversation level). This notion constitutes the conversation among the members of an educational group (teacher, students), which focuses on the pursuit of a certain learning goal. In this way, a "Short Focused Conversation" embraces all the episodes of the dialogue, in which teacher and students negotiate meaning and co-construct knowledge for the pursuit of this goal. These episodes are cited in chronological order.

However, "the same classroom interchange can never mean quite the same for any two people" (Stables, 2003, p. 7) neither involves equal participation from the participants, nor has the same individual learning outcome for all the students participating in it. Therefore, a student participating in a "Short Focused Conversation" for the pursuit of a certain learning goal experiences contextualized individual learning that can be named his or her "Short Learning History" (SLH) concerning that particular learning goal. Thus, from a "Short Focused Conversation" pursuing a certain learning goal we come up with two (2) "Short Learning Histories" (for a dyad of students), each one corresponding to a student member of the group (Fig. 3, First (1st) level of SFC categorization).

In this way, each SFC was analyzed and studied independently for each student participating in the conversation, forming the notion of the "Short Learning History" (SLH) of the student (first (1st) level of SFC categorization) and next the corresponding SLHs were categorized according to the type of Spiral IRF exchanges and learning goal attainment (second (2nd) level of SFC categorization) (Fig. 3). The formation of different types of Spiral IRF exchanges takes into account whether the teacher tunes in to collective thinking emerging from the students' talk or to individual thinking emerging from the responses of one individual student. A SLH is coded "successful" in terms of learning goal attainment in case of the student correcting their answer in the post-test question that evaluates the achievement of the SLH's learning goal. A SLH is coded "unsuccessful" in case of the student responding unsuccessfully in the corresponding post-test question.

3.6.1. *The reason why a coding scheme categorizing a "Short Learning History" in terms of type of spiral IRF exchanges categorizes it in terms of type of "scaffolding" through talk as well*

Since the same classroom dialogue cannot mean quite the same for any two students, it neither involves the same participation nor has the same individual learning outcome, we categorized SLHs in terms of types of Spiral IRF exchanges, instead of categorizing SFCs. Below, we demonstrate that such a categorization classifies the SLHs in terms of types of "scaffolding" through talk as well.

In this study, we investigate and take into consideration only the SLHs of students who had not answered correctly in the corresponding question in the pre-test (diagnostic test). We refer to the question that evaluates the achievement of the learning goal pursued by the corresponding SFC. We have one SFC for each learning goal and each learning goal is assessed by one question in written test. Thus, we assume that the teaching-and-learning activity, which the teacher guides and supports, "scaffolds" the pursuit of the certain learning goal, which is defined as the individual independent ability to respond successfully to the same or to a similar question or exercise in the future (e.g. the evaluation post-test). In this way, while Maybin et al. (1992) approach "scaffolding" as a form of 'help' offered by the teacher, we consider "scaffolding" as the overall teaching-and-learning interaction (see also Dawes, 2004; Mercer & Fisher, 1997; Reid, 1998). Thus, it reflects our belief that it is the overall contextualized conversation and action that begets learning and not just the teaching intervention itself. Therefore, we consider the term "scaffolding" as a "scaffolding process", which is a special kind of teaching-and-learning interaction that meets some certain criteria and may occur in the Short Learning History (SLH) of a student.

Consequently, in the present study, the "Short Learning Histories" (SLHs) were organized in a way that they meet the 1st, 2nd and 3rd criteria set by Maybin et al. (1992), in order to characterize a teaching-and-learning process as "scaffolding process". In this way, if we detect through the analysis of the dialogue that the 4th and 5th criteria are also met, we can argue that a "scaffolding" process has taken place during a Short Learning History of a student. The teaching-and-learning efficacy of this process can later be assessed by evaluation post-test (Criterion 6).

3.6.2. Coding scheme emerged from the discourse analysis

Thus, in a "Short Focused Conversation" it is possible for a student, in contrast to his/her classmate, to participate in a Spiral IRF exchange with his/her teacher (Criterion 4), until there is evidence of the certain student successfully achieving the learning goal with the teacher's help (Criterion 5) (Dyadic Spiral IRF: Scaffolding Individual Thinking (SIT)). In this way, from this "Short Focused Conversation" we come up with two (2) "Short Learning Histories" (SLHs) coded differently in terms of interaction forming "scaffolding". Furthermore, in a SFC it is possible for the students to collaborate in terms of thinking collectively through talk. In such a case, two or more students think together through discussion, while the teacher supports this collective thinking with his/her contributions (Spiral IDRF: Scaffolding Collective Thinking (SCT)). Also, it is likely that in a "Short learning History" there are no Spiral IRF exchanges involving that particular student (Absence of Spiral IRF (AS)), or the student solves the problem and/or utters a correct answer without being "scaffolded" by their teacher (Presenting Competence Without Spiral IRF (PCWS). Finally, there are also some cases, in which there are sequences of IRF exchanges that present problems of loose context and/or continuity (Edwards & Mercer, 1987) and/or they consist of 'loop' or 'closed'[5] IRF sequences (Problematic Spiral IRF (PS)).

In this way, we developed a coding scheme, which emerged from the discourse analysis, in order to categorize, exhaustively, all the SLHs in terms of type of Spiral IRF exchanges. The categories of the coding scheme are listed below:

- Spiral IDRF: Scaffolding Collective Thinking (SCT).
- Dyadic Spiral IRF: Scaffolding Individual Thinking (SIT).
- Problematic Spiral IRF (PS).
- Absence of Spiral IRF (AS).
- Presenting Competence Without Spiral IRF (PCWS).

3.6.3. Internal reliability of the categorization

Since the aforementioned categories and constructs constitute a new coding scheme consisting of new conceptual constructions with the aim of categorizing exhaustively the unit of analysis, it is necessary to calculate the internal/inter-rater reliability of this categorization. We used Cohen's Kappa coefficient to statistically measure inter-rater reliability. Using 19 SLHs coded independently by an external rater, we calculated a value of 0.67. This value is 'good' according to Fleis (Fleis, 1981 reported on Bakeman & Gottman, 1986), whereas for other researchers it is just under the acceptable limit of 0.70 (University of Nebraska, n.d.). So, we detected the categories-constructs that caused confusion and after having a discussion with the external rater, we (a) improved categories-constructs operational definitions as well as (b) re-trained the external rater. Finally, the external rater was given anew 19 different SLHs to code and we calculate the Cohen's Kappa coefficient again, which, this second time, was 0.93.

[5] 'Closed' IRF sequences: Sequences of IRF verbal exchanges in which the teacher focuses on students giving certain correct answers as evidence of individual competence and not on the process of constructing knowledge for the pursuit of correct answers on behalf of the students.

3.6.4. Comparative analysis

After we came up with the enumeration of the categorized SLHs, we had the opportunity – using comparative analysis (χ^2 test-chi square test) and 2×2 contingency Tables – to detect whether there is a statistically significant relation between each of the type of spiral IRF exchanges and learning goal attainment (Fig. 3).

4. Results

4.1. Two types of scaffolding processes

Two types of IRF interaction in a "Short Learning History" of a student meet the criteria set by Maybin et al. (1992) so as to be characterized "scaffolding processes". The first is Spiral IDRF: "Scaffolding Collective Thinking" and the second is Dyadic Spiral IRF: "Scaffolding Individual Thinking".

Spiral IDRF: "Scaffolding Collective Thinking" (SCT) is defined as the type of Spiral IRF in a "Short Learning History" of a student, in which students think collectively through talk (D) in order to respond to a teacher's initiation or, generally, meet the requirements of the task.

We use the coding D to refer to the emergence of collective thinking in peer discussion among students. Collective thinking emerges through exploratory or cumulative talk. In this case, the structure of the discourse is formed as "I-(D_1)-R_1-F_1- (D_2)-R_2-F_2-.". The brackets denote that collective thinking (D) emerges at least once in the "Short Learning History" of the student.

In Episode 1, a "Short Learning History" of student T takes place. Along with student Z and teacher E, student T pursues learning goal 1(a) (Appendix), during the task concerning "Processor" in the "Models Creator" environment.

Comment. Students T and Z along with the teacher E are trying to construct mutual understanding in order to respond to the question concerning the internal operation frequency of the computer processor and the number of synchronization clock cycles per second (Learning goal 1(a)). Specifically, students read the problem from the worksheet while the teacher reframes the question to focus their attention (I). Next, the teacher challenges students' Z first response (RZ_1-F_1)[6] redirecting it to the group. There follows a short excerpt of parallel individual thinking uttered verbally including a second answer on behalf of the student Z (RZ_2) and a first answer on behalf of student T (RT_1). This excerpt of parallel individual thinking may be interpreted as cumulative talk since students may listen to each other and perhaps, while responding to the teacher, complement each other's contribution. This excerpt is the beginning of a short excerpt of exploratory talk (D_1) emerged after the teacher's intervention (F_2). With his intervention (F_2) the teacher confirms RT_1 response and by justifying its correctness he models problem solving thinking strategy, stressing that what matters is the "Mega" unit of measuring. In the exploratory talk (D_1), student Z suggests an explanation of the problem solution; student T challenges student Z's explanation. T's challenge is justified. Then student Z suggests an improved explanation of the problem solution. Student T agrees and repeats the solution to the problem posed. The teacher confirms the right response, stressing the way students should think in similar exercises (F_3). Students complete the articulation of the right answer (RT_2-RZ_3) and the teacher reconfirms its correctness once more.

From the analysis becomes apparent that the teacher 'tunes in' to the students' present state of ability or understanding reflected in discourse. The teacher intervenes, setting mental "scaffolds" through talk until the process of collaborative knowledge construction leads students to express the right answer to the question posed. It is apparent that the ultimate purpose of the teacher is the pursuit of independent individual competence of solving similar exercises in the future (for example evaluation post-test) as well as the gradual construction of mutual understanding regarding the relation between the internal operation frequency of the computer processor and the application software execution time. Furthermore, as the Episode 1 indicates, the teacher does not "scaffold" the thinking of each student separately but the collective thinking emerged as exploratory or cumulative talk.

The particular episode (Episode 1) does not integrate extended excerpts of collective thinking. The aim of its citation is to describe the type of the "scaffolding process" through talk and not to provide evidence that in the present teaching-and-learning context there were extended excerpts of collective thinking.

Dyadic Spiral IRF: "Scaffolding individual thinking" (SIT) is defined as the type of Spiral IRF in a "Short Learning History" of a student, in which students don't think collectively through talk in order to achieve the learning goal of the "Short Focused Conversation". The particular student and the teacher are involved in a continuous Spiral IRF creating context in a dyadic communication relationship until the student provides evidence of dependent individual competence in the conversation. In this case, the structure of the discourse is formed as "I-(RS_1)-(RP_1)-F_1-(RS_2)-(RP_2)-F_2-.". We use the symbol RS to symbolize the Response of the Student of the SLH and RP to symbolize the Response of the Participant–student. The brackets in RP denote that we may or may not have some response by student–participant P, while brackets in RS denote that as soon as context and continuity sustain over time for the dyad of teacher and student S, it is not mandatory to have a response by student S in every I-R-F exchange between them.

In the case of Dyadic Spiral IRF, it is highly likely to encounter some verbal contributions by other participants (RP) which intermingle between the teacher's Initiations (I), Follow ups (F) and the student's Responses (RS). However, those

[6] RZ_1: means the 1st Response of student Z.

Episode 1: Student T SLH during the ''Processor'' task with student Z in the ''Models Creator'' environment pursuing learning goal 1(a).

I		T: "when a processor has an internal operation frequency of 800 Mhz this means that the synchronization clock..."
		E: "per second" / what does it do per second?
		Z: Let's read it again
		T: "when a processor has an internal operation frequency"
		Z: Yeah
		T: [800 Mhz
		Z: [800 Mhz
		T: "this means that the synchronization clock" does
RZ_1		Z: 800 cycles per second
F_1		E: Just 800?
Articulation of parallel individual thinking or cumulative talk	RT_1	T: Not 800..
	RZ_2	Z: but it's in MegaHertz
	RT_1	T: eight hu... million
	RZ_2	Z: eight million per second
	RT_1	T: eight hundred million
F_2		E: eight hundred million / since it is eight hundred Mega
D_1-RT_2		Z: since one Hertz is..
		T: No / since it is in MegaHertz
		Z: One MegaHertz is one million
		T: Yes / 800 million per s..
F_3		E: Isn't it so? / One MegaHertz is one million what about 800?
RT_2		T: per second
RZ_3		Z: 800 million per second
F_4		E: That's right / so it does 800 million cycles

Transcriptional conventions: E- teacher, T, Z-students, "/"- pause in discourse less than 2 seconds, "//"- pause in discourse more than 2 seconds, "["- overlapping utterances, (text)-non verbal activity and comments, ()-unintelligible speech, ""- reading from Worksheet, commas are not used.

contributions by other participants (RP) don't 'tune in' to the student's contributions (RS) so as to develop a sort of collective thinking through talk. In this way, the social involvement through talk by the other participants makes up a difference between the Dyadic Spiral IRF and the Spiral IRF developed in an isolated dyad of a teacher and a student.

In Episode 2, the teacher "scaffolds" a learning activity of converting the decimal representation of a number to its corresponding binary representation. The learning activity takes place in the "Paper and Pencil" environment. The activity evolves into a dyadic Spiral IRF between the teacher and student P regarding the learning goal 2 of the "Numeral systems" task.

Episode 2: Excerpt of student P SLH during the ''Numeral system'' task with student Z in the ''Paper and pencil'' environment pursuing learning goal 2.

I	E: Let's take number 78 ok? / Let's have a minute to do this together / follow my chain of thoughts / which is the biggest number that divides 78? (The weight units of the binary system are already written on a piece of paper that is in front of them)
RZ_1	Z: 64
RP_1	P: 64
F_1	E: 64 / so we use a weight unit of 64 /let's see what we have left / what shall we do to find the number that is left (asks P)
RP_2	P: aaaah
F_2	E: Subtraction
RP_3	P: Subtraction
F_3	E: What is left? / we used a weight unit of 64 here
RZ_2	Z: Yes / 78 minus 64?
F_4	E: 78 minus 64 do you agree P?
RP_4	P: Yeah yeah
F_5	E: Isn't it so? / since I used a 64 unit correct? I want to find out what is left after I used the 64 unit / so I subtract 64 from 78 do you agree? (P nods) / 8 minus 4 equals 4 (Students subtract 64 from 78 on a piece of paper)
RZ_3	Z: [1
F_6	E: [1 so I have [14 left
RZ_4	Z: [ninetee.. / 14?
RP_5	P: 14
F_7	E: 14 is correct / so now from the numbers we have left which one is the biggest dividing 14? (Again, the students are looking at the weight units of the binary system that are already written on a piece of paper in front of them)
RP_6	P: number 8 and number 4 I believe
F_8	E: so...
RZ_5	Z: number 8
F_9	E: number 8 so we have got zero units of 32 and zero units of 16
RP_7	P: Yeah right and [() units of 8

F_{10}	E: [So number 8 / since I use one unit of 8 I have to subtract 8 out of 14
RZ_6	Z: Yes
F_{11}	E: What's left? / Number 6
RZ_7	Z: number 6/ then number 4
F_{12}	E: so we have number 6 left /don't we?
RZ_8	Z: Yes
F_{13}	E: from the weight units left on the right side of the paper..
RZ_9	Z: number 4
F_{14}	E: ..which is the biggest? / Number 4
RZ_{10}	Z: Yes
F_{15}	E: I use a weight unit of 4 I subtract 4 out of 6 and I have number...
RP_8	P: Number 2
F_{16}	E: Number 2 / which is the biggest weight unit from those left that divides number 2?
RZ_{11}	Z: Number 1 hmm number 2
RP_9	P: Number 2
F_{17}	E: Number 2 / a weight unit of 2 divides number 2
RZ_{12}	Z: Yes ()
F_{18}	E: subtracting number 2 the result is zero / since I have found zero I am finished
RZ_{13}	Z: Yes
F_{19}	E: Ok? There is the number ok? (Pointing at P who nods his head)

Comment. The teacher initiates the activity by posing the problem, calling for participation and starting to model the thinking strategy by explaining the process of conversion: "*which is the biggest number that divides.*?" (I). During the activity, he continues to use questions to focus students' attention, elicit students' contributions and model the thinking strategy (F_1, F_3, F_4, F_5, F_7, F_8, F_{10}, F_{11}, F_{13}, F_{14}, F_{15}, F_{16}, F_{18}). He also confirms or repeats and elaborates students' responses and adds relevant information focusing students' attention on the details and important aspects of the problem (F_9, F_{17}). In the beginning of the interaction, twice, he provides direct answers (F_2, F_6) in order to support modelling of thinking strategy but that is stopped as soon as students present an increasing independent competence reflected on their responses. Also, once, he intervenes to pace the tempo of interaction (F_{12}). In initial questions, student P seems to follow the line of thought developed through talk and action, repeating either his participant's responses or the teacher's follow ups (RP_1, RP_3, RP_4, RP_5). The fact that student P follows the line of thought is confirmed by the student's response RP_6. As responses RP_7 and RP_8 indicate, this continuous line of guided thought and knowledge construction continues until the students solve the problem with the help of the teacher. Consequently, in this episode, there is a Dyadic Spiral IRF between the teacher and student P as there is no emergence of collective thinking among the students.

4.2. Evaluation of learning goals attainment

We categorized 262 SLH's in total according to the "type of Spiral IRF exchanges" and "learning goal attainment".

According to the data in Table 1, there is a statistically significant relation between "Scaffolding collective thinking" (SCT) $\chi^2(1, N = 262) = 18.36$, $p < 0.0001$ and learning goal attainment and also between "Scaffolding individual thinking" (SIT) $\chi^2(1, N = 262) = 13.90$, $p < 0.0002$ and learning goal attainment.

As far as SCT is concerned, the relation with learning goal attainment applies to both "educational software" $\chi^2(1, N = 107) = 9.88$, $p = 0.005$ and "paper and pencil" environment $\chi^2(1, N = 155) = 8.52$, $p = 0.0035$. On the contrary, SIT is related to

Table 1
The enumeration of the categorized SLH's.

Short Learning Histories coded		Learning goal's attainment: Successful – Educational Software Environment	Successful – "Paper and Pencil" Environment	Successful – Total	Unsuccessful – Educational Software Environment	Unsuccessful – "Paper and Pencil" Environment	Unsuccessful – Total	**Total**
Type of Spiral IRF exchanges	*SCT*	34	16	50	11	3	14	64
	SIT	18	38	56	8	13	21	77
	PS	3	16	19	15	22	37	56
	PCWS	3	3	6	2	10	12	18
	AS	4	9	13	9	25	34	47
Total		62	82	144	45	73	118	262

learning goal attainment only in "paper and pencil" environment $\chi^2(1, N = 155) = 14.24$, $p = 0.0002$ and not in the educational software environment $\chi^2(1, N = 107) = 1.80$, $p > 0.05$.

5. Discussion–conclusions

5.1. A framework for the analysis of scaffolding through talk in groupwork learning as the pursuit of a learning goal over time

In this study, we introduce a framework for the analysis of scaffolding through talk in groupwork learning, addressing the lack of clarity in the way scaffolding is operationally defined in classroom groupwork learning as teacher-led multilateral or bilateral interaction (cf. Kovalainen & Kumpulainen, 2005 for teacher-initiated multilateral or bilateral interaction in whole classroom context).

Since the role of the teacher in monitoring, coaching or guiding peer groupwork is very important in learning Science and Maths, we study 'scaffolding' as a particular type of teaching-and-learning process that takes into account both teacher–student(s) interaction and peer collaboration. These are two aspects of classroom discourse that, if they are properly integrated, it has been suggested to be the best way to assist scientific understanding (Howe et al., 2000; Mercer et al., 2004a).

This study also provides with a sociocultural framework for investigating the pursuit of curriculum; a sociocultural framework that takes into account the temporal dimension of knowledge construction (cf. Mercer, 2008). The framework analyzes how teacher and students tune into their respective, current states over time in order for the students to accomplish a certain learning goal. It does so in a way that follows individuals' different experiences of an interaction as well as their collective experiences. The discourse that corresponds to "Short Focused Conversation" and "Short Learning History" remains throughout the analysis in chronological order enabling the pursuit of the development of joint understanding over time. This helped to illustrate "why participation in the same educational, discursive events has apparently led to different educational outcomes" (Mercer, 2008, p. 47).

Moreover, this framework involves the complementary use of qualitative and quantitative methods of discourse analysis overcoming weaknesses and exploiting strengths of each type of method (Crook, 1994; Mercer, Littleton, & Wegerif, 2004b).

5.2. Evaluation of the two types of "scaffolding processes"

In the case of Spiral IDRF, teacher and students act as a unified 'cognitive system' (Dillenbourg, Baker, Blaye, & O' Malley, 1996) that shares and constructs meaning using collective thinking in peer discussion (exploratory and cumulative talk) (Mercer, 2000). The discourse between the teacher and the students traces elements of the IDRF structure proposed by Wegerif (2004). In our case, however, the Initiation (I) and Follow up (F) originates from the teacher and not from a computer, while the student's Response (R) is accrued from the peer Discussion (D). The process of Spiral IDRF can be conceived as "Scaffolding collective thinking", which, apart from presenting the educational advantages of collective thinking through peer discussion (D) and curriculum-focused evaluation context of IRF (as discussed in Wegerif, 2004), also presents the advantage of 'spiral' verbal exchanges. In Spiral IDRF, the Follow up verbal move (F) constitutes a start of a new subsequent teaching and learning cycle, with which the teacher "tunes in" to the students' present state of ability or understanding. In this way, the teacher dynamically guides individual and collective thinking to knowledge construction through dialogue. In this context, students take more initiatives in conversation; teacher grants more autonomy to them, while scaffolding is based on participation, in a discourse where differences in perspective are welcomed and encouraged (dynamic scaffolding)

(Askew, Bliss, & MacRae, 1995). However, while "scaffolding collective thinking" presents these educational advantages, there are also obstacles in its application. It is likely that the teacher's verbal intervention functions in a way that – instead of supporting – limits the development of individual and collective thinking since students' experience tells them that their contributions are there to be evaluated in terms of correctness (Edwards, 1992; Wood, 1992). This possibility might partly explain why the research data show rather few episodes of peer discussion (Kovalainen and Kumpulainen (2005) came up with the same results investigating collective problem solving in mathematics). Yet, it is Spiral I-peer Discussion-RF in other words "Scaffolding Collective Thinking" (SCT) that is associated with learning goal attainment across all the environments of the study. The latter finding provides empirical support for the conception of science education as induction into a community of discourse or practice (Lemke, 1990).

In the case of Dyadic Spiral IRF, there is not such a context to ground and develop collective thinking through peer discussion among students. The communication structure consists of a sequence of dyadic spiral IRF verbal exchanges, which are mediated and contextualized by other participants' contributions. This sequence of dyadic spiral IRF exchanges is situated in the dyadic relationship between the teacher and a student and presents continuity in constructing a shared mental context throughout the conversation until there is evidence of "scaffolded" individual competence/assisted performance in dialogue. In the context of our research, there is association between "Scaffolding Individual Thinking" (SCT) and learning goal attainment in the "paper and pencil" environment and in total but not in the educational software environment. Further analysis of the data need to be conducted in order to detect the features of the context that make the difference.

Both constructs of Dyadic Spiral IRF and Spiral IDRF highlight some important aspects of the "scaffolding process" in groupwork learning: (a) teacher interventions, which are contingent upon student's state of ability and understanding and focus on a curriculum aim, (b) development of thinking and reasoning in discussion among students and also (c) continuity in construction of mental context through time until individual competence is witnessed. The major difference between those two types of Spiral IRF in groupwork learning is apparently the emergence of "scaffolded" collective thinking in peer discussion among students. In this way, we consider Spiral IDRF as a process of "scaffolding" collective thinking emerging in a peer discussion among students and Dyadic Spiral IRF as a process of "scaffolding" individual thinking emerging by one student's responses.

The aforementioned findings, which resulted from the evaluation of the two types of "scaffolding processes", add to a theory of classroom practice that might inform teachers' design and realization of teaching-and-learning activities and thus teachers' training (see also Kovalainen & Kumpulainen, 2005).

5.3. Limitations of the study and future plans

The case study discussed in this paper is limited due to the short-term teaching-and-learning activities wherein the teacher aims at his students demonstrating dependent competence within the time the activities lasted (solving the problem with the teacher's help: 5th criterion of Maybin et al., 1992). The short-term nature of scaffolding activities as well as the low to moderate students' capacities are likely to have influenced the teacher (a) to set low to moderate learning goals and (b) to utilize discursive practices in order for his students to provide evidence of dependent competence/assisted performance within activity time. In most cases, he achieved to come up with an evidence of dependent students' competence. Yet, it was the comparative analysis that showed which discursive practices had eventually an impact on independent individual unassisted performance.

Yet, collaborative experiences are typically more than just brief, time-limited, localized sessions of joint activity and it is only by studying the evolution of collaborative activity over extended periods of time that can make us develop a clearer understanding of authentic classroom activity (Littleton, 1998).

Although transition from other- to self-regulation is not an easy task to accomplish (Kovalainen & Kumpulainen, 2005; Rasku-Puttonen, Eteläpelto, Arvaja, & Häkkinen, 2003), longer scaffolding activities might need less intervention on behalf of the teacher and perhaps might trigger longer episodes of collective thinking on behalf of the students (see Panselinas, 2002).

This paper reports on a framework for the analysis of the pursuit of a learning goal over time. We suggest that it would be interesting for a future study to use this conceptual framework ("Focused on a learning goal Conversation", "Learning History of a student") for the study of a student developing a specific skill, grasping a particular concept or achieving a particular level of understanding over a longer stretch of time: "A temporal analysis can help us see how students' ideas change through the extended process of interaction with a teacher and other students, and how new concepts, ways of using language, and ways of solving problems are appropriated" (Mercer, 2008, p. 56).

The aforementioned framework has led to a framework for "scaffolding" in groupwork learning. We have detected and evaluated two types of "scaffolding processes", which take place in school groupwork computer science learning. We have also provided with empirical data in terms of "the relationship between scaffolding activities and the students' actual achievements" (Rasku-Puttonen et al., 2003, p. 390). However, due to the limited generalization of findings and the short-term nature of the case study in hand as well as the context-dependent relation between the two types of 'scaffolding processes' and learning goal attainment, further data analysis and study is needed. We suggest that the study needs to be conducted across different contexts and domains with various learning goals over a longer stretch of time, applying both qualitative and quantitative methods of analysis.

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Appendix

Learning goals of groupwork activities/tasks
Task concerning "processor"
For each student after the teaching-and-learning activity:

- Learning goal 1(a): to be able to fill in the blank of test question 1(a) with validity and accuracy.
- Learning goal 2(a): to be able to fill in the blank of test question 2(a) with validity and accuracy.

Task concerning "Numeral systems"
For each student after the teaching-and-learning activity:

- Learning goal 1(b): to be able to respond correctly to test question 1(b).
- Learning goal 1(c): to be able to give a properly grounded explanation for question 1(b).
- Learning goal 2: to be able to convert the decimal representation of a number to its corresponding binary representation.

Diagnostic (Pre-) and Evaluation (Post-) Tests
Task concerning "processor"
Fill in all the blanks in the given responses of questions 1 and 2

1. What does the internal operation frequency of the core of the processor mean? What is the synchronization clock?
   - When a processor has an internal operation frequency of (800)/(1000)[7] MHz, this means that the synchronization clock
     (a) --per second and each time a clock cycle comes, the processor
     (b) --.
2. What is the processor external data bus? What does the width of a processor external data bus mean?
   - The external data bus of the processor connects the processor with
     (a) --.

Task concerning "Numeral systems"

1. (a) Is there always a decimal representation of an integer number? (b) Is this decimal representation unique or there may be another decimal representation for this particular number? (c) Explain your thinking and answer. --
2. Convert the decimal representation of the number $105_{(10)}/119_{(10)}$[7] into its corresponding binary representation. --

Part of the worksheets of the tasks/activities
Task in DELYS concerning "Numeral Systems"
Sub-task 1

- Empty the Scales. Place 167 weight units on the left tray.
  1. Lock the Scales
  2. Place weight units on the right tray so as the scales balance once you unlock them.
  3. Unlock the Scales.

  Sub-task 2
- Is there any sum of weight units on the left or the right tray, which is not possible to balance? In other words, if I put a number on a tray is it likely not to be able to balance the scales placing weights on the other tray? Explain your thinking and answer.

Task in ModelsCreator concerning "Computer Hardware"
How does internal frequency affect applications software execution time in a personal computer? Create a model that explains that influence.

[7] The first number is used in the diagnostic test (pre-test) and the second one in the evaluation test (post-test).

- Create a model by dragging and dropping the appropriate entities in the models' activity space.
- Select the appropriate properties and a relation.
- Test model's behaviour manually by moving the bar, automatically with button "play" or using the button "step by step".

Let's think:

In which way do changes in internal frequency of a processor affect applications software execution time? How would you explain that?

- When the processor's internal frequency is 800 MHz then the internal clock (a)________________per second, and when a clock pulse comes the processor (b)____.
- Higher internal clock frequency means more (a)____________________ per second, consequently more (b)____________ per second, therefore, applications software execution time (c)__________.

It is possible the answers you have already given to those questions to have led you to change or add something to your model. Integrate your new ideas in the model you have already created and re-test it's behaviour.

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