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Technology as small group face-to-face Collaborative Scaffolding

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ABSTRACT

There is a wealth of evidence that collaboration between learners can enhance the outcomes for all concerned. This supports the theorization of learning as a socio-cultural practice, framed by Vygotsky and developed by other researchers such as Rogoff, Lave and Wenger. However, there is also evidence that working collaboratively may not be a spontaneous response to working in a group, and that teaching learners how to collaborate, and in particular how to work together to negotiate meaning, is a necessary part of the process of learning collaboratively which can enhance outcomes further. A question for the computer supported collaborative learning community then arises as to whether learning to collaborate can be scaffolded through the use of digital tools, and what such tools might look like. This paper reports on the design of a digital system that aims to support the practice of face-to-face collaboration on open-ended tasks. Findings from trials of the system in classrooms in the UK and Chile show that the model is welcomed both by teachers and pupils, and met its objectives of ensuring greater interaction between class members who did not normally work together, and involvement of all individuals in discussion based activities.

1. Introduction

In Vygotsky's view, development is conceptualized as the process by which children grow into intellectual life through interaction with those around them (Vygotsky 1930/1978). From this standpoint, the common posture of attributing thoughts and intentions solely to individual actors is a misconception in the understanding of shared knowledge and group cognition, because it neglects the interactions that arise in the group as the source of development itself, by reducing group phenomena to actions of the individual group members and ignoring their contributions to creation of group meaning. Hence, the social conception of development is related to the short-term negotiation of common ground during interactions (Stahl 2005).

When students have the opportunity to work in small groups, they can contribute to a common understanding, as well as developing verbal and social abilities. Peers work in a common context; therefore, they may have insight into other learner's needs, their focus, and the best way to explain (Lave & Wenger 1991; Rogoff & Lave 1984). Recipients benefit from peer supported learning because they get the opportunity to experience new approaches to thinking. On the other hand, helpers benefit because when they explain their ideas to others, they have to verbalize their understanding, making explicit the difference in what is in his/her mind and his/her utterance, and by doing so obtain a clearer perspective of the topic (Gillies 2006).

Peer learning can be characterized by the type of engagement that is fostered (Damon & Phelps 1989):

- Peer tutoring where one instructs the other.
- Cooperative learning where students form a team where the task to solve is divided between the different team members.
- Peer collaboration where students share ideas to jointly solve the task.

Collaboration by itself does not necessarily yield learning. (Dillenbourg 2002) indicates that effective collaborative learning requires that students engage in a well defined outline of how students should form groups, how they should interact and collaborate and how they should solve the problem. Effective collaboration shows increased participation of the peers in group discussions who then demonstrate

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a more sophisticated level of discourse, engage in fewer interruptions when others speak, and provide more intellectually valuable contributions to those discussions (Shachar & Sharan 1994). Dialogues in small groups are multidirectional rather than bidirectional, as between a teacher and student, or unidirectional, as can occur in peer tutoring dyads. From a Vygotskian perspective, that emphasizes the importance of verbal interaction as a catalyst for promoting thinking, one could expect that multidirectional dialogue exchanges present in small group discussions enhance students' cognitive development (Gillies 2006). This transitive discussion contributes to productive meta-cognitive decisions, by making students think publicly, and exposes their ideas to critical scrutiny (Goos, Galbraith, & Renshaw 2002).

However, small group learning is not a universally endorsed practice. There is still a propensity for teachers to talk and students to listen (Galton, Hargreaves, Comber, Wall, & Pell 1999), For instance, Gillies (2006) indicates that in the UK most children in primary school work alone or with the support of an adult, while in secondary school, grouping practices are aimed at maintaining control and on-task attention, and maximizing individual and teacher-directed learning. Yet when students are grouped teachers feel more comfortable with the role of facilitator and their language is more caring, personal, spontaneous, varied and creative and as they work more closely with the small groups they move among the groups to monitor progress and provide specific assistance. Despite these advantages reported by Gillies, it seems teachers are often reluctant to embrace small group learning since it is an organizational change for the teacher which appears harder and more time consuming than a traditional approach (Baines, Blatchford, & Kutnick 2003). This is true in part because learners do not necessarily spontaneously work together well in groups, and tasks that afford opportunities for meaningful collaboration can be hard to design and manage. The difficulty lies in developing the students' interaction skills, promoting collaborative problem solving, and providing students with emotionally and intellectually stimulating learning environments (Sharan, Shachar, & Levine, 1999).

Various projects have examined the degree to which digital technologies might be employed to support collaboration among learners. In Computer Supported Collaborative Learning (CSCL) (Crook 1994; Dillenbourg 1999), the focus is not so much on the individual who learns and thinks, as on the collaborative group that explores and reasons. Its focus is beyond technology, and research in this area needs to address cognition, communication and both cultural and social settings. Social learning systems, cooperative systems, or collaborative systems adopt a constructivist approach using the computer more as a partner than as a tutor. These systems also use the computer not as a means for directive training but as a way to exchange, control and build knowledge within partnerships, most commonly where partners work at a distance (Ai'meur et al. 2001).

Recent work has addressed a rather different context, where the digital system is designed to support face to face CSCL (Zurita & Nussbaum 2007). This design recognizes two networks; the social network, where group mates interact verbally, and the technological network that transparently supports the social network activities, by coordinating and synchronizing activity states and mediating the activities and the social interaction of the participants (Zurita & Nussbaum 2004).

The approach presented in this paper is a face-to-face CSCL that encourages small group participation. It proposes a collaborative learning activity with three types of actors: the teacher as tutor and mediator, the student as task performer and technology as the Collaborative Scaffolding. The scaffolding is designed to encourage social interactions, facilitate joint problem solving and lead to richer knowledge construction. It aims to provide the means to prompt cognitive and social interactions between the participants involved, which might otherwise not occur.

The proposed model takes language into consideration as a fundamental tool through which learners elaborate thoughts, explain results, evaluate solutions through appropriate feedback, explore and clarify inconsistencies and knowledge gaps, link the verbal information to new strategies and tangible actions, and so benefit from the cognitive restructuring that underpins cognitive change (Fawcett & Garton 2005; Teasley 1995). The organization of the classroom into small groups established by this model fosters the verbalization of ideas (Artzt & Armour-Thomas 1992), and the sequencing of actions based on individual digital tools scaffolds verbal interaction. In this sequence, every student in the classroom is expected to verbalize his/her ideas in order to convince him/herself and his/her group mates of the correctness of his/her views. This allows learners to explore variations between their own and their partner's knowledge (Fawcett & Garton 2005).

2. Designing for Collaborative Scaffolding

The model of collaboration used here assumes that the quality of the engagement fostered depends on improved metacognitive awareness developed through a reciprocal process of exploring each other's reasoning and viewpoints in order to construct a shared understanding. This reciprocal process requires students to propose and defend their own ideas, and to ask their peers to clarify and justify any ideas they do not understand. This kind of reasoned dialogue where ideas are compared with those of another person in order to co-construct understanding, is more complex than simply reaching consensus on an agreed answer and may include disagreement and conflict (Kruger 1993).

Collaboration and group achievement are not necessarily accomplished by assigning students to groups and telling them to work together. The tasks chosen for peer collaboration need to be appropriate to the capabilities of the individual learners and to the collaboration process, and structured so that children must work together cooperatively for successful completion. Integral to this process is the necessity for joint action as well as verbal explanations. In addition, groups should be constructed to include children with different skill levels or perspectives. Such an approach would satisfy the Vygotskian condition of providing information within children's zones of proximal development, and also create the socio-cognitive conflict necessary from a Piagetian perspective (Fawcett & Garton 2005).

The proposed approach introduces technology as a collaborative scaffold that guides and mediates the interactions between students as they work through a structured sequence of information sharing and knowledge construction. The sequence begins with individual participation, moves to (small) group collaboration, and finishes with a teacher mediated whole class discussion.

Fig. 1 illustrates the different phases that form the proposed method. In this model, the groups are composed of three students and formed randomly (Zurita, Nussbaum, & Salinas 2005 drawing on Dillenbourg 1999 and Fawcett & Garton 2005). In phase 0 (Problem Statement), the teacher gives all the groups an activity to carry out, for instance a problem to solve, a simulation to explore, a question to investigate, etc. The task representation appears on every student's screen, and each student is asked to work individually on the job. Then in phase 1 (Individual Response), each student is asked to work individually on the assigned job. In this phase, the students' work is solely based on his/her own understanding of the task and restricted to work with his/her own skills and previous knowledge.

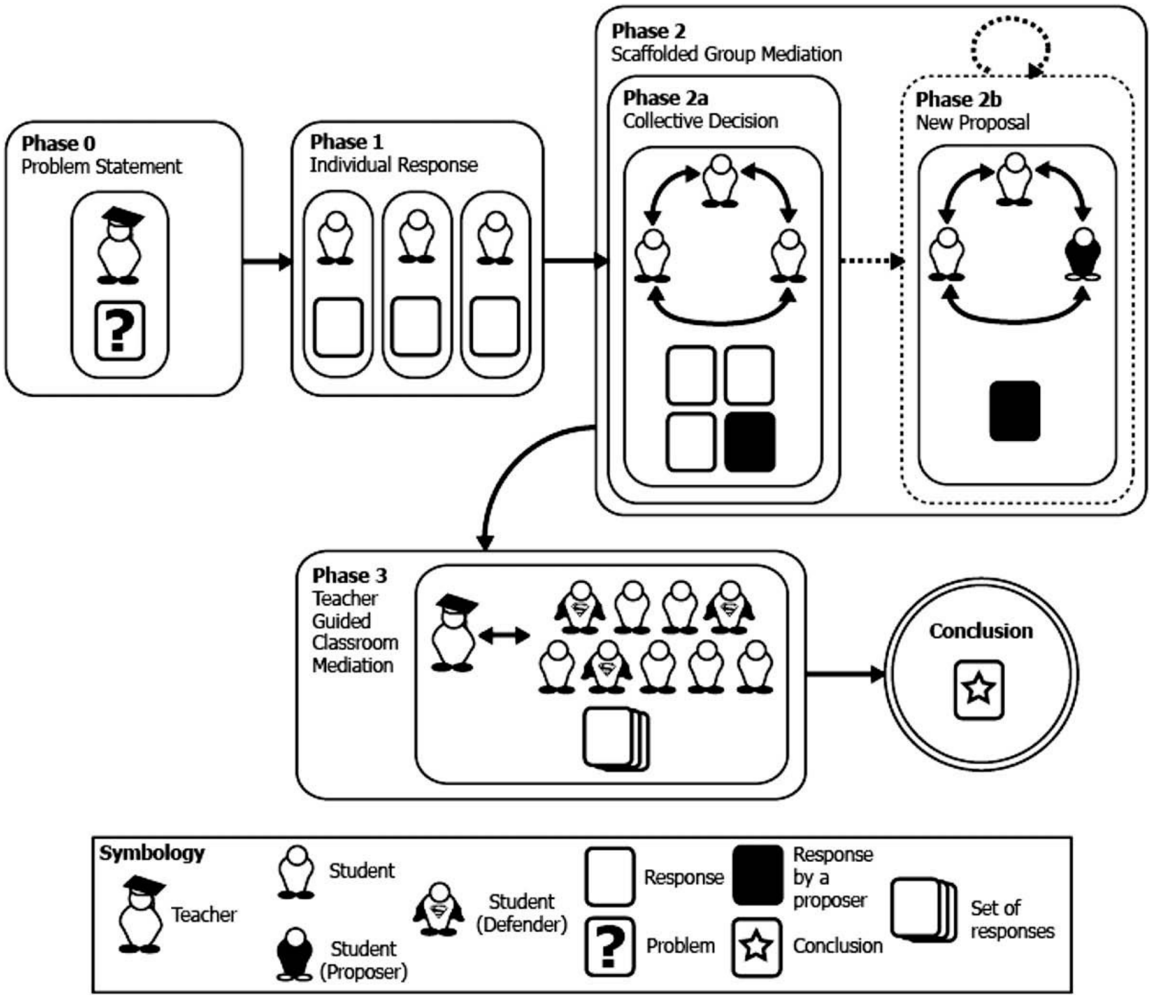

Fig. 1. Technological Collaborative Scaffolding.

Once the three group members submit their individual answers, the scaffolding starts in Phase 2a (Collective Decision) for that particular group. The aim of the Collective Decision phase is to lead the group to construct a consensus, which is the key to social constructivism (Vygotsky 1978). Consensus here means the common understanding of a group, constructed through assimilation or accommodation of new knowledge into existing schemata gathered from experience (Brown, Metz, & Campione 1996). The three solutions generated by the group members in phase 1 are now presented to all of them as eligible options. Each student in the group may select one of the answers that he/she believes better responds to the task. The three students must concur on an answer. If they disagree, the scaffolding does not allow them to proceed. If the students agree that none of the available options is an adequate answer they start Phase 2b (New Proposal) where they construct a new joint proposal.

The New Proposal phase starts by randomly selecting one peer (Proposer in Fig. 1) that is enabled to write the answer that represents all the members' convergent opinion. The other group members wait until the selected group mate completes this task, contributing verbally and observing what he/she is doing. Once the selected group member finishes working on the new group solution, which might draw from the original three responses, the scaffolding sends the answer to the two waiting group mates, seeking their approval. This answer has to reflect their opinions and so they may accept or reject it, and are encouraged by the scaffolding to reach an agreement when both differ. If both reject the new proposal constructed by their companion, Phase 2b is repeated with a new controlling author until consensus is reached.

The Collective Decision and New Proposal phases offer a mediation mechanism that presents a common goal within a synchronous activity, where team mates have to build from a shared conception of the problem that allows co-construction of understanding from continuous communication (Granott 1993; Teasley & Roschelle 1993). When the different group members' answers appear on the students' screens during the Collective Decision phase, the students seek to corroborate their answers by comparing them to their group mates' ones. Thus new alternatives may create at least a momentary dissonance. An internal one, where misconceptions or incomplete information is made apparent, or an external one, with the group mates react by dismissing the subject of dispute as being unimportant or dismiss the other person as being unimportant. The question is how to benefit from the conflicts that arise, while the group mates enter a state of disequilibrium and, hence, engage in the processes of restoring equilibrium, inherent to the Piagetian theory of cognitive change (Piaget 1959).

The group should initiate a debate and negotiate, trying to eliminate the different group members' dissonances by attempting to convince each other by changing the others' opinion to finally converge on a common solution (Ai'meur et al. 2001). However, this will not always happen spontaneously and the teacher will have a key role in encouraging students to explain why they believe a particular answer has merit. The technology here provides the opportunity for a collaborative work space, but the quality of the negotiation will rely on coaching and practice. At best, this process is characterized by an exchange of ideas and opinions between the team members each of whom is working within their own ZPD, and the need for a more knowledgeable tutor is reduced. This affords the possibility for all the members in a learning group to take the role of negotiator (Pata, Sarapuu, & Lehtinen 2005). When the dissonance remains after some negotiation, the group members seek new information or the teacher's support. The role of the scaffolding here is to ensure that consensus is achieved since the group cannot proceed to the next stage until each member of the group has agreed to the same proposal.

The teacher still has a crucial role to play in orchestrating fruitful collaboration. The scaffolding offers visibility of the phases the groups are going through, as well as their final responses. Students' thinking can become confused without the teacher's guidance, the key issues being when and how the teacher should intervene to assist students to select strategies, identify errors, and assess the group's work. The teacher has to know when he/she might be misdirecting, causing confusion, or denying the group the opportunity to resolve their own difficulties, and to encourage persistence while avoiding frustration (Goos et al. 2002).

Since groups are formed randomly, group mates may have different zones of proximal development, benefiting from the interaction with adequate language and behavioral traits (Fawcett & Garton 2005). We use the requirement of stating what is previously known by the student in Phase 1 (Individual Response), to introduce the discussion in the next phase, Collective Decision. In this phase, as the individual responses are visible to all group members, they all have the opportunity through peer review to see, reply to and argue with each other's responses, thus enabling the group to develop a common answer. They can examine all responses to the problem while constructing their reflective conclusion, therefore having the opportunity to develop their thinking until they submit a group solution (Hughes, Ventura, & Dando 2004). Once the weaker student understands the group solution and corresponding arguments, they can construct their own internal problem representation. They might even use the criteria developed by the group in a literal way, if asked by the teacher to support the group answer in the Teacher Guided Classroom Mediation phase. The open discussion that occurs in small groups enables participants to clarify ideas and perspectives in a context that is free of the perpetual scrutiny of the teacher and the wider class group (Howe 1990). Phase 2 finishes once the students reach an agreement, sending the corresponding answer to the teacher as the groups' consensual response that the groups' members have compromised to support.

Considering that up to now students don't know if what they have done is adequate or correct, Phase 3 (Teacher Guided Classroom Mediation) starts when the teacher selects a sub-set of the received answers with the highest potential for facilitating a whole classroom discussion where all the students together, mediated by the teacher, explore the teacher selected responses to the initiating task. Once the teacher completes the selection, the scaffolding dispatches the chosen set of responses to all the students' devices. The scaffolding then randomly selects one representative from each of the teacher's selected groups, indicating the selection through the corresponding learner's device. These representatives (Defenders on Fig. 1) are meant to explain the reasons why they support the answer submitted by their group. In this way, the group members are encouraged to take accountability for their decisions. The teacher performs an active role by mediating with and between the students to reach a common agreement. When agreement is not reached, the teacher must continue to arbitrate and finally indicate her/his final opinion about the topic.

The teacher's task is more than coaching the answering process; it is giving the appropriate guidance to achieve the students' understanding. The teacher's chosen student's (partial) comprehension of the solution, evidenced through their responses, is the grounding element of the discussion. The student must be engaged in active turn taking with the other students and the teacher. The internalization of the answer has to be a process jointly elaborated by the different actors. The teachers' role is to find coherence with the different students' answers and observations (Pata et al. 2005). This is also a powerful mechanism for exposing learner misconceptions, which the teacher may or may not choose to reveal to the rest of the class.

3. ColPad, an application of technology mediated Collaborative Scaffolding

A collaboration script is a set of instructions prescribing how students should form groups, how they should interact and collaborate and how they should solve the problem, (Dillenbourg 2002). The main components of the collaboration script are the epistemic script, which specifies how learners work on a given task, and the social script, which structures how learners interact with each other, (Weinberger, Ertl, Fischer, & Mandl 2005). In the previous section, we presented a scripting approach where the epistemic and social components are blended. In Phase 1 (Individual Response), Fig. 1, learning is personal with no social interaction, with technology providing the space to present the individual answer. In Phase 2, (Scaffolded Group Mediation), learning is supported through the peers' social interaction mediated by technology to ensure convergance. Finally, in Phase 3 (Teacher Guided Classroom Mediation) learning is supported by the teacher's social mediation with the whole classroom, where technology supports by informing the teacher of the different groups' answers and by selecting and notifying the students who have to explain their group's answer. Even this model could be implemented without technological support, technology allows it to happen smoothly. Technology provides the means to organize the work and interactions among students in a classroom, making them follow the three phase script, Fig. 1, which prevents the free-rider effect (Salomon & Globerson, 1989) since one group member is not able to take or relinquish control, and reduces the teacher's and students' cognitive loads (Dillenbourg 2002), as they don't have to memorize and execute the script, which is automatically performed by the technology.

The presented Collaborative Scaffolding offers an open framework which can accommodate different knowledge domains in the classroom. Such generality is achieved because it is an abstract model that does not explicitly involve any specific concrete input for the generation of knowledge representations. It is therefore completely independent of the input that generates the representations of problems and their solutions, allowing any knowledge domain to be the subject of teaching and learning following a constructivist methodology.

In most traditional classroom practice, students use paper and pencil to make their annotations, write compositions and solve mathematical problems, among many other possible tasks. CollPad aims to support work in any domain where knowledge representations can be generated using paper and pencil, following the constructivist methodology of Collaborative Scaffolding.

The input for the Collaborative Scaffolding in CollPad is a virtual piece of paper presented on the touch screen of a handheld device, on which users may draw, write and erase using the stylus. Fig. 2 shows an example of this instance of the Collaborative Scaffolding (notice the parallels with the general model presented in Fig. 1). In the example, after all the members of the group in Phase 1 submit their individual answers, the three different graphical representations of 1/4, there must be a negotiation to decide which answer to submit. When explain-

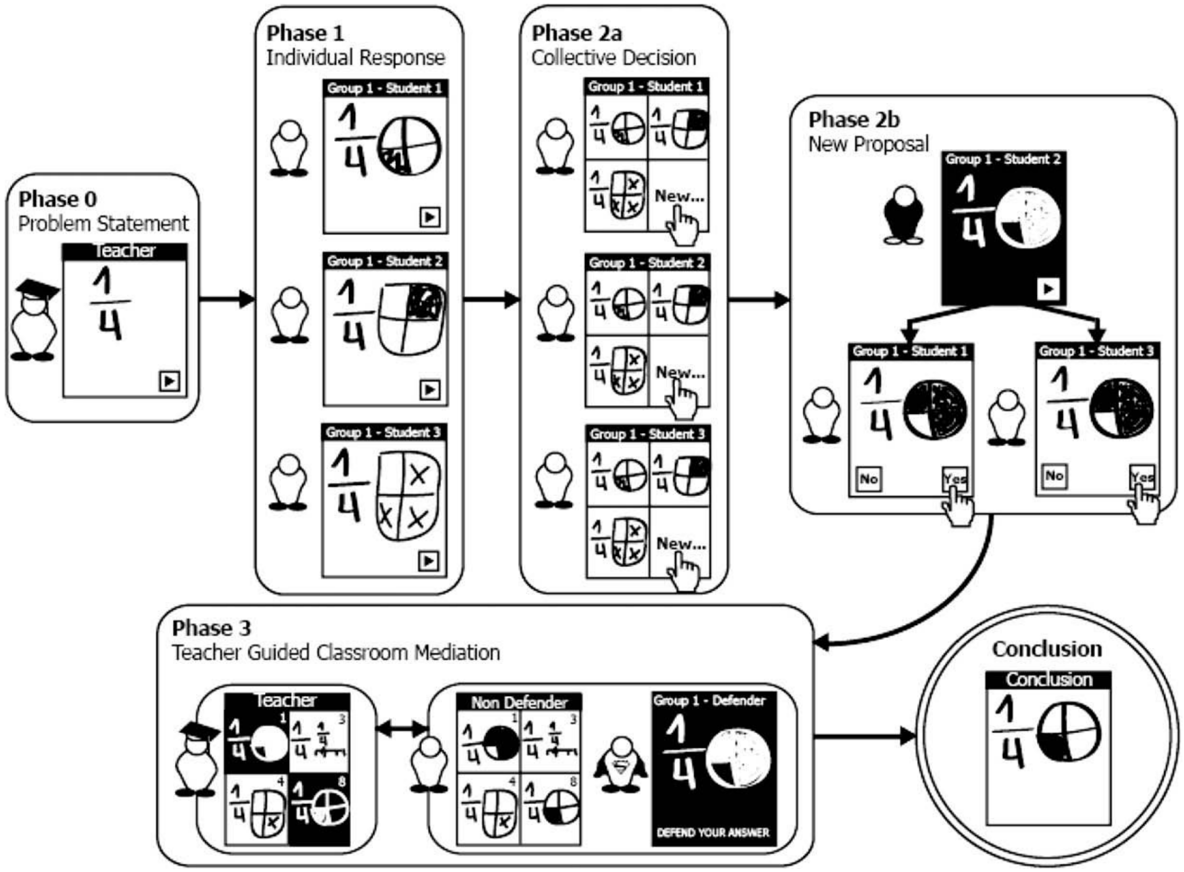

Fig. 2. Collpad Example.

ing their answers to each other in Phase 2a they may decide to write a new solution collectively, Phase 2b. One of the students is randomly selected by the system and the other two have to agree to accept or reject the answer written by the selected student. Once they agree to accept it, the answer is sent to the teacher, otherwise the system repeats this cycle until they converge. In phase 3, the teacher decides to initiate a discussion involving responses from groups 1, 3, 4 and 8 (supposing that there are at least eight groups in the classroom). A student from group 1 is randomly chosen by the system to defend the answer submitted by his/her group, while the other students in the classroom receive the set of answers selected by the teacher and take part in the discussion. The teacher guided classroom discussion, in this case, has the aim that the children come to recognize the right answers and that the answers from groups 4 and 8 are the same.

CollPads' use can be also exemplified at high school level with a physics question: On a warm day, should a mother wrap an ice cream with aluminum foil, a fabric, or a paper to stop it melting? The children have to work out that the aluminum foil has a better thermal conductivity than the others, and the paper is a better insulator. In this case, the problem statement, phase 0, is verbally specified by the teacher, giving the students a blank virtual page to answer. In the individual response, Phase 1, the students write a couple of sentences on their screens indicating their answers. At the collective decision, Phase 2a, if they agree, even if it is wrong, they might continue, being the teacher at Phase 3, teacher guided mediation, responsible for catching the mistake. Otherwise, (at Phase 2a) they discover their divergences, prompting a cognitive conflict which should bring up a conceptual discussion; in this case the difficulty of the problem is the misconception of associating temperature with materials, thinking that while the aluminum feels colder it will cool the ice cream. Finally, at Phase 3 the teacher brings up the misconceptions from the different groups, selecting those group answers that will show, through the concept of thermal conductivity, that the key here is energy transfer.

4. Experience with CollPad

We trialed an implementation of CollPad in three schools in the UK, involving five 6th grade teachers for a month (Galloway 2007; Whyley 2007), and in Chile with three math high school teachers in two schools also for a month. In both cases, wirelessly interconnected Pocket PCs were used (Fujitsu Siemens Pocket Loox 720 and N560 in the UK and HP RX1950 and Dell Axim 50 in Chile).

In each case, UK and Chile, the children in the trial had experience of using the PocketPCs for some time, and so they were familiar with the basic operation of the device. However, the CollPad application did require a couple of hours of training for the teachers in managing the sequence of operation of the software, and the connection of the machines to the wireless network. Teachers had direct methodological support in the first session; the guidance was mainly directed to the Teacher Guided Classroom Mediation phase. Key aspects are the detection and management of students' conceptual mistakes by formulating questions that confront the students' answers to uncover their errors. On average, after four trials in front of the students they felt comfortable with the methodology and the tool that supported it. Technical support was required to set the router and the machines.

While in the UK CollPad was used from Math to Art to English with great fluency, in Chile it was used in Math and Science. We observed differences in teachers' philosophies of learning; while the Chilean teacher focused on the result, the English centered on the strategy. In the teacher guided classroom mediation, Phase 3, Chilean teachers examined with students why an answer was right or wrong, compared with the English ones that analyzed why the error was made. CollPad supports this last type of teacher to address strategies. As one English teacher said: "having an immediate X-ray of students' thinking", when he realized that he taught three methods to solve a multiplication, receiving answers from the groups with five different schemes.

The development of social skills is a primal point of the Collaborative Scaffolding model. In order to facilitate socialization the working groups of three pupils are randomly allocated by the software. On start up each child receives a group number and has to locate the other two children with the same group number. Children have to learn to work with any group mates which breaks cliques; groups are no longer formed on the grounds of ability or friendship, race or gender. This aspect was welcomed by all the teachers, who found it difficult, in regular group work, to insist that children work with individuals they did not like. With CollPad, when new groups were formed, in some cases individuals did approach the teacher to say they did not want to work together, but when the teacher responded that the hand held network assigned the groups and there was nothing he/she could do about they accepted this explanation. Very quickly this random allocation became normalized and the pupils interviewed volunteered that they welcomed this element as they found they could work with children they had previously thought they would not get along with.

At the first sessions, we observed some students not knowing what to answer individually relying on the teacher or peers. In the following sessions, they were used to the activity dynamics and prepared themselves during the lecture to have some personal opinion, or knowing where to search for information to be able to answer individually. It was noticeable that the younger children, both in individual and group work, required more teacher mediation than the older ones. Students realized quickly that they had to engage in all phases to have enough and adequate arguments when asked by the teacher in the teacher guided classroom mediation, Phase 3. The quality of the small group discussion phase was dependent on the question type and difficulty; when no personal interpretation was possible, all answers were about the same, almost no debate took place, and the students rapidly converged to the same answer. However, when the answer was not obvious to them, they used different criteria to converge: proof of which answer was the correct one, choosing the one that appeared most or the one with most data, convinced by peers, voting, or making a random choice. In the last phase, Teacher Guided Classroom Mediation, the teacher selected answers that were right and wrong to highlight the reasons for erroneous reasoning.

One purpose of the trial was to see if the teachers integrated the technology into their daily teaching. In the month of the project, all the teachers achieved this aim; they understood the pedagogy behind the model, and learned how to develop appropriate content to foster discussion. Also, they were in sympathy with the philosophy behind the approach, and wanted to develop their use of group and class discussion. All teachers reported that there was greater involvement of all pupils in discussion using the CollPad scaffolding, which they found impossible to achieve using teacher moderation alone. Both the teachers and students highlighted that students learned to give their personal opinion on topics they would never normally tackle, to converge in a discussion and be an active learner inside the classroom. Teachers observed that CollPad offers insight into children's thinking. After group work finishes the teacher instantly receives their outputs, allowing close tracking of progress. Some indicated that in-class management is therefore improved helping the teacher to plan their interventions in the class, and target his/her time.

5. Discussion

The Collaborative Scaffolding presented follows the ground rules for exploratory talk in groups described by Wegerif, Mercer, and Dawes (1999) and Gillies (2006):

1. Tasks are open.
2. All information is shared.
3. The group seeks to reach agreement.
4. The group takes responsibility for decisions.
5. Reasons are expected.
6. The group task requires contributions from all members of the group.
7. Alternatives are discussed before a decision is taken.
8. All in the group are encouraged to speak to other group members.
9. The teacher's role is to act as a facilitator and guide during the cooperative learning activities.
10. The group makes decisions in a democratic way, and they are expected to be accountable.

Naturally, it is entirely possible to design and manage tasks that afford the opportunity for learners to experience all these elements of collaboration without resort to any digital scaffolding. However, we know that effective collaboration must be learned and requires guidance, instruction, and training (Blatchford, Kutnick, & Galton 2003). Left to their own, groups may not work well together; one member may dominate, some may choose not to participate, and there may be no discussion of the thinking behind the decisions made. Technology scaffolding helps to keep all groups on task, while the teacher is free to visit any group that requires support and facilitate their group discussion.

Even with the help of technological scaffolding, teachers have to be prepared to work with groups and prepare lessons that make use of collaboration (Rummel & Hauser 2006), and understand what constitutes quality peer learning, which among other things depends on the development of the skills to share metacognitive roles such as idea generation, problem solving strategies and validation (Goos & Galbraith 1996). The teachers' role remains vital in defining an adequate task and in mediating the Teacher Guided Classroom Mediation Phase, where the child either validates his answer, discovers what his group did wrong, or opens his thinking to new scenarios.

Due to the synchronous characteristic of CollPad, children have to wait until all group members finish Phase 1, individual response, and have to wait until all groups complete Phase 2, submission of proposal, to proceed to the next phase. This sometimes produced disruptions inside the group and classroom disturbance. A way of coping with this is that the system could explicitly indicate to the children the remaining time for each phase to accommodate their individual and collective working period.

From the two examples of Section 3 we can see that a very wide range of problem type can be handled. The sole restriction is the Pocket PC 240x320 pixel resolution touch screen display that limits the students' expression to simple drawings and/or phrases of not more than 25 words. CollPad has been ported to Windows XP. Using the mouse to input on a bigger screen and the keyboard to input text, allows elaboration not only in the drawings but also in the phrasing. Additionally, the possibility of having more than one window in an XP machine allows students to have access to a browser to search for information, or to a spreadsheet or simulator to model, which enriches the individual response phase and supports the group mediation.

6. Conclusion

The model offered here does suggest that appropriately designed technology can support the use of group discussion within a constructivist model of knowledge building. This is achieved by moderating the contributions of individuals and ensuring an exchange of views that leads to consensus building in the group. The close co-ordination of interactions cannot be moderated by the teacher for all groups simultaneously, but by communicating each group's progress to the teacher, the system can help the teacher to make the most effective interventions. A trial of this system in a small sample of schools, in two countries, shows that the model is welcomed both by teachers and pupils, and met its objectives of ensuring greater interaction between class members who did not normally work together, and involvement of all individuals in discussion based activities.

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References

Ai'meur, E., Frasson, C., & Lalonde, M. (2001). The role of conflicts in the learning process. *Sigcue Outlook, 27*(2).

Artzt, A. F., & Armour-Thomas, E. (1992). Development of a cognitive–metacognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction, 9*(2), 137–175.

Baines, E., Blatchford, P., & Kutnick, P. (2003). Changes in grouping practices over primary and secondary school. *International Journal of Educational Research, 39*, 9–34.

Blatchford, P., Kutnick, P., & Galton, M. (2003). Towards a social pedagogy of classroom group. *International Journal of Educational Research, 39*, 153–172.

Brown, A. L., Metz, K. E., & Campione, J. C. (1996). Social interaction and individual understanding in a community of learners: The influence of Piaget and Vygotsky. In A. Tryphon & J. Vonèche (Eds.), *Piaget–Vygotsky: The social genesis of thought* (pp. 145–170). East Sussex: Psychology Press.

Crook, C. (1994). *Computers and the collaborative experience of learning*. London, UK: Routledge.

Damon, W., & Phelps, E. (1989). Critical distinctions among three approaches to peer education. *International Journal of Educational Research, 13*, 9–19.

Dillenbourg, P. (1999). *Collaborative learning: Cognitive and computational approaches*. Amsterdam, The Netherlands: Elsevier Science.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL Can we support CSCL.* (pp. 61–91) Nederland: Heerlen, Open Universiteit.

Fawcett, L. M., & Garton, A. F. (2005). The effect of peer collaboration on children's problem-solving ability. *British Journal of Educational Psychology, 75*, 157–169.

Galloway, J. (2007). When three is not a crowd The Guardian of London (UK), Education supplement. June 19. Available at: http://education.guardian.co.uk/elearning/story/0,,2105774,00.html [accessed April 21, 2008].

Galton, M., Hargreaves, L., Comber, C., Wall, D., & Pell, T. (1999). Changes in patterns of teacher interaction in primary classrooms: 1976–96. *British Educational Research Journal, 25*(1), 23–37.

Gillies, R. M. (2006). Teachers' and students' verbal behaviors during cooperative and small-group learning. *British Journal of Educational Psychology, 76*, 271–287.

Goos, M., & Galbraith, P. (1996). Do it this way! Metacognitive strategies in collaborative mathematical problem solving. *Educational Studies in Mathematics, 30*, 229–260.

Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics, 49*, 193–223.

Granott, N. (1993). Co-construction of knowledge: Separate minds, joint effort, and weird creatures. In R. H. Wozniak & K. W. Fischer (Eds.), *Development in context: Acting and thinking in specific environments* (pp. 183–207). Hillsdale, NJ: Erlbaum.

Howe, A. (1990). A climate for small group talk. In M. Brubacher, R. Payne, & K. Rickens (Eds.), *Perspectives on small group learning*. Oakville, Ontario: Rubicon (pp. 101–118).

Hughes, M., Ventura, S., & Dando, M. (2004). On-Line interprofessional learning: Introducing constructivism through enquiry based learning and peer review. *Journal of Interprofessional Care, 18*(3), 263–268.

Kruger, A. C. (1993). Peer collaboration: Conflict, cooperation or both? *Social Development, 2*, 165–182.

Lave, J., & Wenger, E. (1991). *Situated learning*. Cambridge, England: Cambridge University Press.

Pata, K., Sarapuu, T., & Lehtinen, E. (2005). Collaborative scaffolding in synchronous environment: congruity and antagonism of tutor/student facilitation acts tutor scaffolding styles of dilemma solving in network-based role-play. *Learning and Instruction, 15*(6), 571–587.

Piaget, J. (1959). *The language and thought of the child* (3rd ed.). London: Routledge.

Rogoff, B., & Lave, J. (1984). *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University Press.

Rummel N., Spada H. & Hauser S. (2006). Learning to collaborate in a computer-mediated setting: observing a model beats learning from being scripted. In Proceedings of the 7th international conference on learning sciences (Bloomington, Indiana, June 27 - July 01, 2006). *International Conference on Learning Sciences* (pp. 634–640) International Society of the Learning Sciences.

Salomon, G., & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research, 13*(1), 89–100.

Shachar, H., & Sharan, S. (1994). Talking, relating, and achieving: Effects of cooperative learning and whole-class instruction. *Cognition and Instruction, 12*(4), 313–353.

Sharan, S., Shachar, H., & Levine, T. (1999). *The innovative school: Organization and instruction*. Westport, CT: Bergin & Garvey.

Stahl, G. (2005). Group cognition in computer-assisted collaborative learning. *Journal of Computer Assisted Learning, 21*, 79–90.

Teasley, S. (1995). The role of talk in children's peer collaboration. *Developmental Psychology, 3*(2), 207–220.

Teasley, S. D., & Roschelle, J. (1993). Constructing a joint problem space: the computer as a tool for sharing knowledge. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 229–258). Hillsdale, NJ: Erlbaum.

Vygotsky, L. (1930/1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Wegerif, R., Mercer, N., & Dawes, L. (1999). From social interaction to individual reasoning: An empirical investigation of a possible socio-cultural model of cognitive development. *Learning and Instruction, 9*, 493–516.

Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005). Epistemic and social scripts in computer–supported collaborative learning. *Instructional Science, 33*(1), 1–30.

Whyley, D. et al, (2007). Learning2Go. http://www.learning2go.org/pages/collaboration-eduinnova.php [accessed April 21, 2008].

Zurita, G., & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers & Education, 42*(3), 289–314.

Zurita, G., & Nussbaum, M. (2007). A conceptual framework based on activity theory for mobile CSCL. *British Journal of Educational Technology, 38*(2), 211–235.

Zurita, G., Nussbaum, M., & Salinas, R. (2005). Dynamic grouping in collaborative learning supported by wireless handhelds. *Educational Technology & Society, 8*(3), 149–161.