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A NEW CONCEPTUAL FRAMEWORK FOR CSCL: SUPPORTING DIVERSE FORMS OF REFLECTION THROUGH MULTIPLE INTERACTIONS.

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Abstract. While traditional computer-supported learning environments (i.e. desktop PCs) have been show to promote collaboration they have been largely constrained by the confines of a classroom setting. With the influx of wireless technologies, new opportunities have been opened for designing novel computer-supported environments that support a wider range of collaborative interactions. For instance, collaboration can take on different forms, such as, adult-child collaboration or peer-peer collaboration, local or remote collaboration involving different forms of mobile communications. Moreover, depending on the type of collaboration, learners can experience a different kind of interaction, which can enable them to reflect in different ways. Using multiple collaborative interactions that facilitate diverse forms of reflection allows us to begin to explore the learning process in more detail. This paper presents a new conceptual framework for investigating and analysing how multiple collaborative interactions may support different forms of reflection. The framework is used here to analyse and inform the design of a novel mixed reality learning environment for children.

1. INTRODUCTION

The conventional view of computer supported collaborative learning (CSCL) has centred primarily around desktop computers, where learners share mice and screens, and where action and interaction is limited by the constraints of desktop computing. Consequently, models of collaboration for computer-supported learning tend to be limited, focusing on one dimension of potential collaborations, such as: peer-peer; child groups; adult-child; or computer-child interactions. In contrast, according to Rorty (1991; cited by Savery and Duffy, 1995), knowledge evolves through social negotiation and evaluation of individual understanding. One aspect of this involves challenging others about their views, as well as reaching an understanding of their world through collective agreement. Collaboration is essential for learning knowledge, involving a diversity of collaborative interactions. How might technology be used to better support different kinds of collaborative activities in an integrated way?

One possibility is to use wireless technology and ubiquitous computing since they provide opportunities for designing for a range of collaborative interactions to take place, "allowing students to engage in highly collaborative activities anywhere" (Luchini et al., 2002). In particular, mobile technologies allow interaction with the physical world at the same time as the digital world, moving computing and interaction away from the constraints of the desktop. In so doing, children can collaborate in a more active way within the real physical world, as well as the

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physical world being augmented through digital technology. This not only offers a novel way of interacting with the environment, but also provides opportunities to design for multiple kinds of collaboration to support learning. To support new forms of collaboration requires us to think of how best to design ubiquitous and mobile technologies. To this end we need a conceptual framework that matches the opportunities and constraints of the technologies to the possible range of collaborative interactions. What is needed, therefore, is a new conceptual framework that incorporates a wider model of interaction, and which takes into account more diverse and integrated forms of collaboration. Our paper describes how we developed such a framework to inform the design and analysis of collaborative learning. We show how this was applied to the evaluation of a mixed reality learning environment aimed at promoting collaboration in co-located and remote locations over time, space and activity.

2. BACKGROUND

Several theories of cognition and development advocate various types of collaboration to be beneficial for learning. Piagetian theory advocates peer-to-peer interaction as that between 'equals', enabling discussion that can result in cognitive restructuring in a way that adult-peer interactions do not because of the asymmetry of the relationship (Tudge and Rogoff, 1989). On the other hand, Vygotskian theory of development advocates adult-child collaboration as being important for development on the basis that a more 'able' partner can facilitate the development of knowledge and skills by scaffolding their activity. Apprenticeship learning has also demonstrated benefits of adult/ child collaboration on the basis of 'more advanced' to 'less mature' interaction. A large body of research has shown the benefits of these different kinds of collaborative interactions and collaborative activity for learning. Peer-peer collaboration, where two or more learners are working together, has been shown to help in understanding another's perspective, participating in a more complex enterprise, encouraging models of behaviour, and improving academic performance (e.g. Tudge and Rogoff, 1989; Rogoff, 1990; Topping, 1992; Wood and O'Malley, 1996). Peer-peer collaboration works for various reasons: peers speak at a level that they each understand; peers are more likely to challenge one another where they would just accept adult opinion; peers are motivated to resolve contradictions; and feel less threatened than when interacting with adults (Damon, 1984). Particular types of intellectual stimulation have also been suggested to arise from working with peers, that are not gained as easily when interacting with an expert adult (Crook, 1994). Research has also shown the benefits of a 'tutoring' kind of collaboration, with a more able peer or an adult teacher/tutor, and where the partner provides a 'scaffolding' kind of interaction (e.g. Saxe et al., 1984; McNaughton and Leyland, 1990), or where learning takes place collaboratively, but on-line (e.g. Lally and de Laat, 2002). Other research in computer-supported learning contexts has primarily viewed tutoring-based collaboration in the context of individually based intelligent tutoring systems, where computer software provides the scaffolding, perceived to be required by learners. In addition to the usefulness of

these systems to promote learning, research suggests the continued importance of social interaction through classroom discussion is still considered as playing an important role (Mark, 1997; cited by De Boulay and Luckin, 1999). Theories and empirical research have suggested a wide-ranging number of learning benefits to be gained from a variety of collaborative interactions, each one offering advantages for learning in different ways.

One of the main benefits is the potential to engender various forms of reflection (e.g. Boud et al., 1985; Ackerman, 1996; Scaife, 2002). This is often achieved through reflection, where verbal expression (a form of externalisation) is instrumental in the collaborative process itself. By 'self explaining' learners become aware of their own discrepancies in understanding, enabling them to revise their model of understanding (Chi, 1997). Through externalizing learners, amongst other things, express opinions, seek for clarification, interpret, explain, dispute, generate and test ideas, and elaborate, all of which can be facilitated through collaboration."One way in which learners may gain from working closely on a problem is by being required to make their thinking public and explicit" (Crook, 1994, p.133). We believe it is this explicit awareness that enables learners to reflect more, and in so doing facilitating the advancement of their understanding.

In contrast with much previous research in CSCL that has focused primarily on one form of collaboration, our research is concerned with using technology to support a variety of different collaborative combinations. In particular our focus is on digitally augmenting interaction with the physical world, so as to enable learners to be more mobile and engage in a variety of different collaborations. Our underlying aim is to provide diverse kinds of interactions that promote reflection through externalisation. To this end, we developed a new conceptual framework.

3. CONCEPTUAL FRAMEWORK

As noted, collaboration can take on different forms, depending on the collaborative relationship and interaction. We propose that each kind of collaborative relationship facilitates different kinds of externalisations that provoke reflection. Below we describe the different types and then consider how they can both be promoted and supported.

Verbalising ideas in collaborative interactions enables learners to be aware, not only of their own discrepancies in understanding (as with the 'self explanation' effect), but also their partner's discrepancies in understanding. This compels them to express their own knowledge, requiring them to articulate their understanding, which may uncover further discrepancies of their own. Alternative collaborative interactions can prompt learners to express themselves and push their skills of enquiry further. For example, an adult/tutor providing a guiding role can encourage learners to elaborate their understanding, through prompting or asking searching questions. In addition, communication can take on different forms according to whether collaboration occurs locally or at a distance. Communicating at a distance, e.g. via walkie talkies, demands a higher level of description of a frame of reference

than when face-to-face. To begin we propose a general framework that supports the following kinds of collaboration:

Form of collaboration	Location
Peer-to-peer	Co-located
Peer-to-adult	Co-located or remote
Group	Co-located and remote

Central to our conceptual framework is working out how to support multiple interactions or collaborations in n integrated way, so that each collaboration brings its own benefits, but all collaborations fit seamlessly together to more comprehensively support reflection. This means designing the learning experience such that several different collaborations are supported. A key question is how best to integrate the collaborations to provide a coherent learning experience that allows the children to sometimes take the initiative and sometimes be guided. The focus for adult collaborators may, at times, be on guiding and facilitating, rather than directing activity, allowing more control to come from the learners. At other times the collaborative support may be more directive. Our aim is to design learners' activities that can be supported in a flexible manner that encourages various forms of reflection.

4. INFORMING THE DESIGN OF A NOVEL LEARNING EXPERIENCE USING THE CONCEPTUAL FRAMEWORK

Our framework provides us with a way of thinking about how to design for multiple collaborations that can engender reflection. We designed a novel learning experience to take place outdoors, rather than in a classroom, as this allows for a more diverse set of collaborative interactions. We also developed a range of interconnected learning activities to engage children with their immediate physical environment. To support the different collaborative interactions we used a variety of pervasive technologies: walkie-talkies for remote collaboration; PDAs (handheld personal computers) for displaying information; probe tools and 'pingers' (radio frequency transceivers) to elicit information; and GPS (Global Positioning System) to track the children while they moved around. In addition we designed a novel device like a periscope that enabled the children to view augmented digital information on a display (Wilde et. al, 2003).

The design of the learning experience was intended to support collaborative activities, including exploration and discovery that would elicit multiple kinds of reflection. Our pedagogical goal was to support the development and application of scientific enquiry skills when learning about ecosystems and habitats. Scientific enquiry, typically, involves a number of interdependent and iterative stages, namely; exploring, discovering, making and testing hypotheses through experimenting, consolidating knowledge, and reflecting. The learning experience was designed for 10-12 year olds, and comprised a series of activities intended to enable children to learn about habitat distributions and interdependencies within them. Two contrasting habitats with different distributions of organisms and interdependencies were

selected for this purpose: an open clearing and a wooded area. The habitats were augmented with digital information, presented as sounds, animations, abstract visualisations, voice-overs, video clips or images, representing the various aspects of the habitat and the processes underlying them. The children accessed this information by walking past 'pingers' placed in particular locations. The elicited information was presented to them on PDAs. In addition they used digitally-enhanced probing tools to take light and moisture readings (two core parameters that affect the state of a habitat) and to, later, compare these across the different parts of the habitat. To facilitate their understanding and application of the different components of scientific enquiry, the learning experience was loosely structured into three stages: *(i)* exploring and discovering, which took place in the woodland; *(ii)* reporting back, consolidating and hypothesizing, which took place in a purposely designed informal classroom setting on site; *(iii)* experimenting and reflecting, which took place back in the woodland.

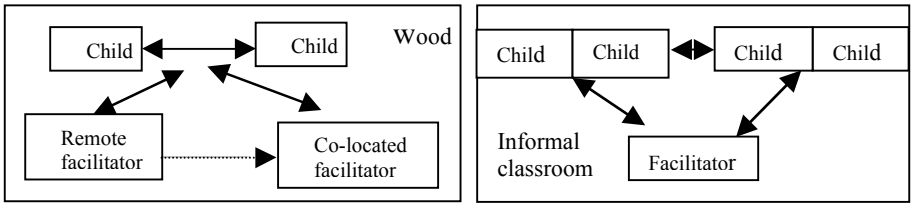


Figure 1. Framework for collaboration

Based on our general framework of collaboration, the different stages of the learning experience were designed to accommodate a diversity of interactions between the children and facilitators in different settings (see Figure 1). Bold arrows indicate direction of potential interaction, and the dotted arrow indicates the co-located facilitator's access to the remote facilitator's interactions with the children. This combination of collaborative interactions was intended to encourage children to generate ideas, formulate questions, express opinions, revise ideas, and begin thinking towards a higher-level of understanding. Thus, there were primarily four different permutations of collaborative interaction: *(i)* peer-peer *(ii)* learner(s) with co-located facilitator *(iii)* learner(s) with remote facilitator, and *(iv)* peer group with adult facilitator .

During the exploring phase of the learning activity the children worked in pairs (one pair in each habitat), with shared goals and shared activities. This enabled them to explore their habitat, collect data, build and integrate their knowledge around the activities they were engaged in and the information they discovered together. To support exploration activities and awareness of others' actions they were provided with wireless technology tools, namely walkie talkies and the probing tool. Using these tools required overt action from a child and were easily picked up by their partner. The children were accompanied by a co-located adult facilitator to guide

them in the woodland. Primarily the facilitator kept in the background to allow the children to explore by themselves, and to assist them as required, namely, reminding them of their task, helping with technology devices, scaffolding their exploration, answering questions, and encouraging externalisation. This level of interaction was achieved by asking questions such as, "Why do think that is? What do you think that means?" To facilitate retention and integration of the information discovered, the children were required to relay their discoveries back to a second adult facilitator. This facilitator was located remotely, and communication took place via walkie-talkies. This from of interaction required the children to describe and explain at a different level of detail than with co-located collaborators. On receiving reports from the children the remote facilitator would embellish or clarify the information to the children as well as prompt them for more elaboration. This not only enabled peer and adult-child interaction, but also enabled adult facilitators to support peer collaboration and interaction. It also transpired at times that the two facilitators together offered enhanced support, for example, through clarification and building on previous interactions with the other facilitator. This part of the learning experience was also designed to be less structured in terms of task goals (i.e. not in the form of sequential rigid steps to go through with task papers or structured worksheets, as is frequently the case in traditional learning situations). Instead a more open kind of activity was designed to allow the children more freedom in their exploration, providing them with direction and control, while at the same time providing support and guidance from the adult facilitators.

The reporting back and consolidating stage took place in the informal classroom setting in a purpose built space where the children sat down away from the exploring area. A large computer monitor and shared interactive display were provided to support this. The session provided a different kind of collaborative interaction, being led by an adult facilitator, whose role was more directive. The session was also structured to elicit particular kinds of reflection, for example, explaining, consolidating, making links, making comparisons and making predictions. The children sat in a group around the computer screens and were encouraged to report back to each other, collaboratively reflecting and consolidating their findings. In particular, this session aimed to enable the children to step back from the physical action of exploring in the wood, and to think more explicitly and holistically about the collection of readings they had gathered in the two habitats, and the processes and relationships between the organisms within those habitats. To enable this, they had access to their probe readings on a computer, which displayed the collections of readings from both habitats, allowing comparisons to be made. In addition the children used tagged tokens of organisms from the habitats in conjunction with an interactive board, to reconstruct their environment whilst explaining interdependencies to explain relationships within their habitats. They also received feedback on the accompanying computer screen at given times.

By designing the learning experience in this way a source of collaboration was provided, not only in terms of expertise (adult/child), but also in terms of communication methods (face-to-face/remote) and style of collaboration (directive/ non directive), each of which promote different kinds externalisation and reflection.

5. USING THE FRAMEWORK TO ANALYSE DIFFERENT FORMS OF REFLECTION

Video recordings were taken of all children engaging in the learning experience and provided the basis for our analysis. Our primary focus was to discover how different types of collaborative interactions engender reflection in learners, and what kind of reflection each facilitates. Although there were several permutations of interaction that could be analysed, the following groupings were focussed on: child/child interactions; child/child to co-located facilitator interaction; and child/child to remote facilitator interaction.

We identified different descriptions of learners' verbal expressions as evidence of externalisation. To do this, two of us independently viewed and took notes and descriptions from video recordings of the children. We then engaged in an iterative cycle of identifying descriptions of verbal expression, reviewing the video to confirm these descriptions, and finally developing a classification of children's externalisations. This classification can be subdivided into externalisations made by the children (e.g. generating ideas, clarifying, explaining, reporting) and contributions made by alternative collaborators (e.g. prompting, structuring activity, asking for elaboration). As we were interested in finding out what kinds of externalisations the learners made, what or who triggered these reflections, what kinds of patterns of communication might emerge in the process of the different collaborative interactions and evidence of any kinds of patterns of reflection, a table was devised to indicate this information (see table 1 for an example extract of interaction. 'WT to den' refers to child communicating with remote facilitator, using a walke-talkie). In particular it we were interested in analysing interactions between the children as well as their interactions with the facilitators.

Table 1 shows a small excerpt of each kind of collaboration and demonstrates the interaction between the three main types of collaboration identified here. In the above example, a child/child collaboration (indicated with *) shows how one child seeks clarification of her own understanding from her peer, which elicits her peer to generate more ideas about the information they are discussing. Together this enables them to give joint explanation. Our analysis also showed further evidence of discussion occurring between the two children in this way. This indicates that peer interaction enables discussion leading to 'cognitive restructuring' in a way that adult-child interaction does not facilitate (Tudge and Rogoff, 1989); and that particular types of intellectual stimulation arise from working with peers that are not gained as easily when interacting with an expert adult (Crook, 1994).

Collaboration between the co-located facilitator/child (indicated by **) shows how a request to elaborate on previous utterances elicits further explanation from a child. This process similarly occurs with the remote facilitator (indicated by ***), who, in this example, also prompts them to think further, which causes them to revise their ideas. Here the remote facilitator is also confirming their understanding, thus supporting them in their reflection. Furthermore it can be seen from this extract how the co-located facilitator can pick up on interactions between the remote facilitator and children, and continue to encourage them to expand their reflections further (see bolded text).

Table 1. Example extract from interaction

Initiator			*Externalisation by children*	
Child action	*Remote facilitator*	*Co – located facilitator*	*Child/child*	*Child/child*
Pinged info.			Gives clarification	Seeks clarification
		Structures activity		
WT to den WT to den	Asks for elaboration	 **Confirmation**	*Seeks clarification	Reports *Generates ideas *Gives explanation
		****Asks to elaborate**		**Gives explanation
   WT to den	Asks for elaboration ***Asks for elaboration ***Prompts Gives clarification			Gives explanation ***Gives explanation ***Revises idea Seeks clarification

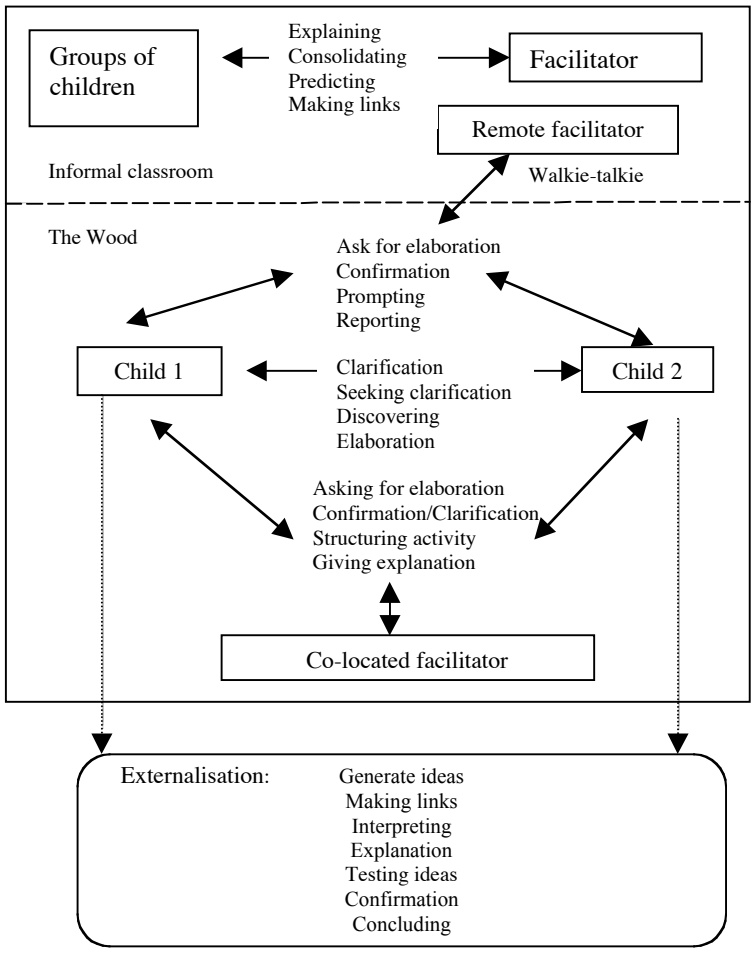
Although we can identify aspects of a process of interactions between pairs of collaborators that promote reflection, it is critical that these are also seen as a sub-process to the overall integrated collaboration between all members. Discussion between child-child occurred as a result of the collaboration between facilitator and child, just like the co-located facilitator-child collaboration was sometimes an outcome or extension of the remote facilitator-child collaboration.

6. DISCUSSION AND CONCLUSION

New pervasive technologies have enabled the design of quite different learning experiences from traditional ones, providing an opportunity to explore the different roles of collaborative interaction and their value in engendering reflection. Our conceptual framework is useful in helping us to identify more explicitly the processes involved in collaborative interaction and to articulate the different forms of reflection it promotes. Our examples suggest that different collaborations have different processes underlying them and trigger different kinds of externalisations from learners. It enables us to begin to identify specific features of the interaction process and how these features relate to particular kinds of collaborations. In addition, it enables us to identify the mechanisms that may engender particular externalisations that are an important part of reflection. From this we can, thus, develop a more comprehensive framework of collaboration, showing how diverse collaborative interactions promote externalisation in the learner, facilitating reflection (see figure 2). The framework is generalisable to other learning settings where there are alternative combinations of technology and groupings. Furthermore, it can be extended to look in more detail, for example, at individual differences within collaborating pairs and their reflection outcomes. In addition, the framework

helps us to design different activity spaces and collaborations, demonstrating that collaboration in computer-supported learning contexts is more than sharing technologies, but is about different kinds of interactions that support multiple reflections.

Figure 2. Extended framework of collaboration eliciting externalisation



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