Computer-Supported Collaborative Inquiry in Remote Networked Schools

Sandrine Turcotte

Department of Educational and Counselling Psychology

McGill University, Montreal

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À la mémoire de Gabrielle Saint-Laurent.

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Abstract

This study addressed computer-supported collaborative scientific inquiries in Remote Networked Schools. Three dyads of grade 5-6 classrooms from remote locations collaborated using the knowledge-buildng tool Knowledge Forum. Customized scaffold supports embedded in the online tool were used to support student understanding and practice of an authentic inquiry process. The study studied how the use of the scaffolds could help students to understand and put into practice an authentic inquiry process, how the students' collaborative problem solving could translate into a deeper understanding of the phenomena explored and if this could lead to conceptual change. Students created notes and used the scaffold supports to support their inquiry process however without sufficient direct teacher modeling, coherent use of the scaffolds stayed low across activities. Pre- and post-test results show that the students gained a better understanding of the inquiry process, but low post-test scores suggest further need for direct teacher modeling of the inquiry process during science instruction. Content analysis of the ideas expressed by the students in two of the sites showed that students were able to generate high-level ideas especially when the directives were explanation-seeking rather than fact-seeking in nature. Teacher mediation in the online discussion tended to generate longer threads than when teachers were absent from the online environment. Unless effective collaborative conversation is already a part of the classroom culture, efforts are required to generate richer student interactions and foster deeper understanding. Recurring technical and logistical difficulties in the sites prevented teachers from concentrating on the learning

objectives and should be more seriously addressed by school authorities. Evidence of conceptual change was found through micro-analysis of the students' ideas about buoyancy in the pre- and post-tests as well as in their notes showing that conceptual change is possible in this innovative collaborative learning context. Further insistence for students to complete the inquiry process is needed in order to created additional opportunities for students to express their knowledge about a scientific phenomenon and promote deeper understanding through collaboration.

Résumé

Cette recherche a pour objet l'étude d'investigations scientifiques menées en collaboration dans l'*École éloignée en réseau*. Trois dyades formées de classes de 3ème cycle d'écoles différentes ont collaboré avec l'outil de co-élaboration de connaissances, Knowledge Forum. Des échafaudages ont été utilisés pour soutenir la compréhension et l'utilisation d'un processus d'investigation scientifique. La recherche a exploré comment l'utilisation des échafaudages a pu aider les élèves à comprendre et mettre en pratique le processus d'investigation, comment la résolution de problèmes en collaboration a pu se traduire en une compréhension plus complète des phénomènes explorés et si ceci pouvait mener au changement conceptuel. Les élèves ont créé des notes et utilisé les échafaudages du logiciel pour soutenir leur processus d'investigation. Par contre, sans modelage suffisant de l'enseignant, l'utilisation cohérente des échafaudages est restée assez faible d'une activité à l'autre. Les résultats aux tests ont démontré que les élèves ont développé une meilleure compréhension du processus d'investigation, mais ils suggèrent aussi un besoin accru de modelage du processus par les enseignants. L'analyse des idées des élèves dans deux sites montre que les élèves ont généré des idées de haut niveau surtout lorsque les consignes étaient de nature à générer des explications plutôt que des faits. La médiation en ligne des enseignants tend à générer des fils de discussion plus longs que lorsque les enseignants sont absents de l'environnement en réseau. À moins que des conversations collaboratives efficaces fassent déjà partie de la culture de classe, des efforts sont nécessaires pour générer des interactions riches entre les élèves qui sont essentielles à une

meilleure compréhension des phénomènes explorés. Des difficultés techniques et logistiques récurrentes dans les sites ont empêché les enseignants de se concentrer sur les objectifs d'apprentissage et devraient être plus sérieusement résolues par les décideurs. Des preuves de changement conceptuel ont été identifiées dans l'analyse des idées des élèves indiquant que le changement conceptuel est possible dans un environnement d'apprentissage innovateur comme celui-ci. Insister davantage pour que les élèves complètent leurs processus d'investigation aurait créé de plus nombreuses opportunités pour l'expression de leurs connaissances et aurait ainsi permis l'apprentissage plus complet des phénomènes par la collaboration.

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Introduction

This study addresses computer-supported collaborative scientific inquiry between remotely located schools using a design experiment approach. Over the years, educational research has demonstrated the educational value of collaboration (see Palincsar, 1998; Rogoff, 1998; among others). Three statements summarize the general rationale behind this study. First, the most powerful theory of learning to date, Vygotsky's socio-constructivism (1978; 1986), states that cognition is first social then individual, opening the door to an ever-increasing interest in the study of sociocognitive processes to account for learning. Collaboration provides interaction opportunities for learners that foster these processes. Second, because learning at the individual level happens "inside the head," so far the best way to study individual learning processes has been to study an individual's discourse *about* learning or *during* learning. Interaction discourse generated through collaboration generates rich and authentic learning contexts to investigate learning in action, including individual and social learning processes. Third, classrooms offer numerous and authentic opportunities for collaboration between students of different backgrounds, personalities, skills and interests: they offer numerous opportunities for identifying and creating multiple zones of proximal development, an auxiliary hypothesis of Vygotsky's theory of learning. As such, classrooms present uniquely rich contexts to study human cognition as collaboration.

The innovative context of this study is particular in itself. The *Remote Networked Schools/École éloignée en réseau* (RNS) initiative investigates the conditions for the use of information and communication technologies (ICTs) as a viable solution to the problem of the accessibility and quality of elementary and secondary school education in the remote regions of Quebec (Canada). The participants of this study are currently engaged in this initiative and have been developing new classroom practices that imply conducting collaborative learning activities between elementary classrooms of remote locations using computer tools such as Knowledge Forum to support learning.

In this study, three RNS sites conducted collaborative scientific inquiries between two grade 5 and 6 classrooms of different locations using the Knowledge Forum (to support their learning process). In addition to developing new classroom practices pertaining to the use of these tools, the participants in this study specifically developed their understanding of an authentic inquiry process through the use of computer prompts embedded in the Knowledge Forum.

Building on a comprehensive review of the literatures relevant to the socio-constructivist perspective on learning, science education, inquiry and conceptual change research, as well as findings from studies of computer-supported collaborative learning, this study addresses the following research questions:

1. How can the use of prompts (scaffold supports) to support the inquiry process in class and online help students better understand and put into practice an inquiry process, individually and collectively?
2. How does the students' online collaborative problem solving translate into a deeper understanding of the phenomena explored?

3. Can this particular collaborative problem solving context lead to conceptual change? If so, what are the characteristics of students' conceptual change in this learning context?

The first chapter of this thesis presents the conceptual and theoretical framework developed to inform this study. The second chapter describes the methodology used to answer the research questions addressed. The third chapter presents the results of the quantitative analyses conducted on the entire data set and answers the first research question. The fourth chapter presents the qualitative analyses conducted on a smaller portion of the data set and answers the second and third research questions addressed. The fifth chapter presents how this study has generated original knowledge and contributed to the field of applied cognitive science. A general discussion of the results obtained and their implications for student learning and professional development follows. Challenges of computer-supported collaborative learning in science are also addressed. Finally, the limitations of this study are presented.

CHAPTER 1 – THEORETICAL FRAMEWORK

The purpose of this conceptual and theoretical framework is to explore and discuss the relevant literatures needed to answer the following question: what are the characteristics of elementary school students' conceptual change when they collaborate to conduct inquiries in science while being supported by a knowledge building tool? In order to answer this question, a four-part chapter will be developed. First, we will define and discuss a socio-constructivist perspective on learning and how it relates to collaborative problem solving in elementary school science education. In the second part of this chapter, we will explore and discuss seven theories of conceptual change, one of which will emerge as being the most powerful to inform this research. Third, we will discuss the general findings and issues from research on collaborative scientific inquiry at the elementary school level. Finally, we will explore the role of the mediating factors, i.e., teacher, peers and/or computer, in a particular collaborative learning environment: classrooms using a knowledge building tool, Knowledge Forum, to conduct collaborative inquiries in science.

Socio-Constructivism and Collaborative Learning

In this section, we will look more closely at socio-constructivism and collaborative learning. To this end, two questions are addressed: (a), what theories of learning support collaborative learning and why? and (b), what are the empirical findings that support collaborative learning? To answer these questions, we will first define and discuss the most salient theory in education for the last 40 years, Vygostky's cultural/historical theory, often referred to as socio-constructivism (Vygotsky, 1978, 1986; Wertsch, 1985). We will then discuss various theories and models that have since been derived from the Vygostkian perspective and examine how they in turn relate to collaborative learning. Throughout, we will discuss some of the empirical evidence that has been found in recent years that support the importance of collaborative learning.

From Socio-Constructivism to Collaborative Learning

From a historical perspective, socio-constructivism can be understood as the convergence of the soviet developmental theory (Vygotsky, 1978; 1986), Piaget's cognitive development theory (1952) and Bruner's constructivist theory (1960). In Bruner's theoretical framework, learning is an active process in which learners construct new ideas or concepts based upon their current and past knowledge. Bruner based much of his work on Piaget's cognitive development theory. According to this theory, cognitive development consists of constant adaptation to the environment through two processes: assimilation (use of the existing structures to make sense of the environment) and accommodation (change of the cognitive structure to make sense of the environment). Piaget derived from this theory four stages of development and recognized the role of social interaction in cognitive development.

At the same time and throughout his career, Vygotsky's main concern was with how human mental functioning is influenced by its historical, cultural and institutional context (Vygotsky, 1978; 1986). To resolve this problem, he developed a theoretical framework that can be summarized into three main themes. The first one has to do with the developmental nature of human cognitive processes. This implies that in order to understand mental functioning, one must take into consideration its origins and the transformations that happen through its development. The second main idea of his theory is that individual higher cognitive processes have their origin in social processes, before being internalized and thus, individualized. Contrary to Piaget then, social interaction is not only a factor of higher mental processes development but rather is the very motor of its development. The role of what Vygotsky called "intermental" functioning in shaping "intramental" functioning led to the development of the notion of zone of proximal development (ZPD): " it is the distance between the actual developmental level as determined by the independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86).

The third main idea in Vygotsky's work is that socio-cultural signs and tools mediate higher mental functions, the most important of which is language (1978; 1986). The mediating action of the tools between the subject and the object are the basis of what was later called the Activity Theory[1]. Many authors have since adopted the Activity Theory (Engeström, 1999; Cole & Engeström. 1993; Bracewell & Witte, 2003; among others).

The essence of Vygotky's theory is that human activity consists of constructive action between subject and object mediated through artifacts and symbols. According to Vygotsky, psychological tools, such as signs, symbols and

[1] Vygotsky himself never used the term Activity Theory. In fact, his student Leont'ev (1978) introduced this term when he was forced to break from Vygotsky possibly because of political pressures. Following this, his work emphasized Marxist concepts and terms such as tools and division of labor as we can see from his Activity Theory schema (see Bracewell & Witte, 2003). Because Leont'ev pursued nonetheless the research agenda initiated by Vygotsky, it is now understood that Vygotsky founded the Activity Theory research program.

language, mediate all higher psychological processes. Adults teach children these tools through joint activity, children internalize the tools and then these tools can function as mediators of the children's own psychological processes.

Thus, cognition is a developmental process that is first social then individual (internalization). As such, optimal cognitive development implies social interaction. One hypothesis that is particularly promising is the role of mediation in the zone of proximal development (ZDP). This topic led to many research programs that investigate learning settings, best practices, conditions and new learning processes that involve some degree of collaboration. We now discuss some of the issues and questions raised by the idea of collaborative learning.

Building on the work of researchers from the Soviet and Western schools that recognized the importance of social interaction in the development of cognitive processes, cognitive psychology in North American gave way to a more socio-constructivist perspective that puts the learner at the center of the learning process and that promotes the construction of knowledge through collaboration. While Piaget recognized the role of interaction in cognitive development, Vygotsky defined interaction as the actual driving force of this development, therefore putting heavy emphasis on the role of social interactions in learning. Many research programs have since been designed to explore the nature and impact of collaborative learning. Others have led the way to different understandings of cognition and cognitive processes. Others still have addressed the different features of classroom interaction. The following sections explore some of these interwoven branches of research.

The Social and Situated Nature of Cognition

The socio-constructivist perspective not only influenced the way teaching and learning as a social process occurs but has also impacted on the conceptualization of the nature of cognition from something happening individually "inside the head", to something that could also have a social nature, a *socially shared* cognition (Salomon, 1993; Rogoff, 1998). This process implies socially shared resources that are made available to others in order to help them go beyond their individual capacities. This change of paradigm has had a profound impact on the way we think about cognition and consequently, how we choose to study it. If we believe that learning activities that are set to operate within the different zones of proximal development of the students will lead to better learning outcomes than individually-oriented ones, then we must take into consideration the distributed as well as the individual cognitive processes that are involved when we study those activities. In other words, instruction should be oriented towards individuals but the key issue is the appropriate social context for instructional activities to promote learning (R. J. Bracewell, personal communication).

A number of authors have addressed issues of individual and distributed cognition (e.g., Cole, 1991; Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999; Wertsch, 1991). In the edited volume *Perspectives on Socially Shared Cognition*, authors from different backgrounds explored how this change of perspective has affected their work (Resnick, Levine, & Teasley, 1991). Wertsch clearly states "the basic tenet of a sociocultural approach to mind is that human mental functioning is inherently situated in social interactional, cultural, institutional, and historical context" (p. 86). Such an approach is thus radically different from one that would examine mental processes independently of their sociocultural context. Cole (1991) claims that some will consider social interaction as another of numerous factors that influence individual thoughts, and therefore will see no particular challenge to their usual practice; others will call for a fundamental revision of the dominant contemporary psychology scientific program. We agree with the latter.

> When one turns to this aspect of the problem – the way in which children come to acquire the complex systems of knowledge that organize joint activity among people in *any* culture – the issue of socially shared cognition jumps to the forefront, because nothing is so certain than those systems of knowledge are not "in" the child's head to begin with. Whatever the mechanisms of their acquisition, they cannot be acquired in a sociocultural vacuum. Hence, if one is to study human cognition as it is encountered in normal human adults, it is necessary to start not with cognitive processes abstracted from their context, but with the structure of activity that provides the functional matrix of and structural constraints on their acquisition. (Cole, 1991, p. 410)

Cole also points to the need to define a unit of analysis that "avoids reduction to either the individual mind or the social group" (p. 413). This position should not only impact the way to conduct research on learning but also our conceptualization of what cognition and thus learning is.

For Rogoff (1998), cognition is a collaborative process. Her "transformation as participation" view is concerned with how people's roles and understanding change as activity develops, how different activities relate to each other and how one prepares for what is ahead based on what one has experienced in the past (p. 690).

> Sociocultural theories such as transformation of participation approach have a premise that individual, interpersonal and cultural processes are not independent entities. Analysis may primarily focus on one of them, but not

> without reference to the others as if they could exist in isolation from each other. (Rogoff, 1998, p. 687)

Drawing from research on expertise and *situated learning* (Lave & Wenger, 1991), Collins, Brown and Newman (1989) put forward the idea of *cognitive apprenticeship* through which a learner is actively engaged with an expert in a problem solving activity for which he wishes to learn the knowledge and skills. Building on the idea that formal schooling is relatively recent in human history, the authors propose that many complex skills are learned informally through apprenticeship-like methods that are observation, coaching and successive approximation (p. 453). In cognitive apprenticeship, the learner is invited to engage as soon as possible in the task, even before he has fully understood or mastered it. The role of the "teacher" is to model for the learner, to coach, and to scaffold the learner and then to fade out from the activity as the learner is gradually able to take more and more responsibility in the task. Here too, the notions of interaction and zone of proximal development and legitimate peripheral participation are inherent in the learning process. The "apprentice" and the expert collaborate to complete the task and through collaboration strategically scaffolded by the teacher, the student is gradually becoming apt at performing the task on his own.

Collaboration, Interaction and Communities of Learners

From the perspective of developmental psychology and also interested in the role of interaction in learning, Brown (1997) developed a program of research named Fostering a community of learners (FCL). Bruner (1996) described the four principles of learning guiding the design of a community of learners, based on his observation of FCL classrooms (Brown, 1997). They are (a) agency i.e., the students take responsibility and ownership of their mental process, (b) reflection i.e., the students develop metacognitive skills, (c) collaboration, "no one is an island, no one knows it all; collaborative learning is necessary for survival" (Brown, 1997, p. 411), and (d) culture, "a culture of learning, negotiating, sharing and producing work is the backbone of FCL" (Brown, 1997, p. 411). In the FCL program, teachers and other adults visiting the classroom, the children themselves, and computers act to support the work of the community of learners.

As part of this program, Brown and Palincsar's work on reciprocal teaching (RT) has focused on questioning, clarifying, summarizing and predicting as comprehension-monitoring devices (1997). RT has proven to be a successful instructional intervention. Its value as an effective instructional intervention for poor readers has been documented in various studies (Brown & Palincsar, 1989; Palincsar & Brown, 1984, 1989; Rosenshine & Meister, 1994) and RT has been integrated into classroom practices in many educational settings since. This provides further evidence in favour of a socio-constructivist perspective on learning. Further work by Brown and Campione (1994) on guided discovery also reported evidence to support this perspective. A series of instructional interventions (reciprocal teaching and jigsaw among others) are presented in their paper and the positive results associated with them are numerous and highly significant. Designed to foster multiple ZPDs through which the students can evolve at different rates, the ideal classroom according to the authors is also intentionally designed to allow for interaction and rely heavily on the assumptions of shared discourse and common knowledge as well as individual expertise (Brown & Campione, 1994, p. 267).

Other researchers have studied the ideas of *community of learners* and *learning communities*. Despite certain distinguishing factors, if we look at them at a broader level, i.e., as collaborative learning environments, we cannot deny their importance as they provide additional insight on collaborative learning. Building on Brown and Campione (1994), Bielaczyc and Collins (1999) have identified four characteristics that define a *culture of learning*: (a) a diversity of expertise among its members, (b) a shared objective of continually advancing the collective knowledge and skills, (c) an emphasis on learning how to learn and (d) mechanisms for sharing what is learned. The article stresses that such an approach fits with the growing emphasis on lifelong learning as well as it encourages interaction between students and other members of society.

Other researchers have discussed the potential role of technology to support different types of learning communities (Breuleux, Laferrière, & Bracewell, 1998; Clayton, 2002; Jonassen, 1995; Kruger, 2000; among others) and despite their varying stance on the specific nature of the collaboration they wish to support with technology, they all share a common interest in the development of collaborative environments to promote effective learning.

Classroom Interaction and Discourse

A third branch of research, closely linked to collaborative learning, studies classroom interaction in different learning contexts. Kaartinen and Kumpulainen (2002) reported a case study investigating collaborative inquiry and the construction of explanations in science. The results show a reciprocal relationship between the communicative and cognitive processes of discourse in the collaborative setting. They also show that the collaborative nature of this science-learning situation effectively supported the students' conceptual elaboration of solubility.

Palincsar and Herrenkohl (2002) discussed the design of collaborative learning contexts. Building on RT research spanning over a decade, they found "that students who participated in groups that were heterogeneous with regard to comprehension ability attained competence more quickly than students in groups that were homogeneous" (p. 31). As for their work on cognitive tools and intellectual roles (CTIR), the students used a set of cognitive tools that focus on: (a) predicting and theorizing, (b) summarizing results, and (c) relating predictions and theories to results. The cognitive tools support student collaborative inquiry by providing a shared focus for their interactions. The three cognitive tools were also developed into assigned roles for the audience.

> Some audience members were responsible for checking the reports for clarity regarding the relationship(s) between predictions and theories, others were responsible for ascertaining the clarity of the summary of findings, and some were responsible for determining if the reporter discussed the relationship(s) among their group's prediction, theory, and findings. (Palincsar & Herrenkohl, 2002, p. 29-30)

The use of these tools: (a) supported classroom dialogue, (b) advanced student theorizing, (c) influenced student thinking about the nature of scientific problem solving, and (d) promoted conceptual understanding. The authors state that the context allowed the students to practice many thinking skills under the expert guidance of the teacher as well as with the help of tools.

Starting from a historical overview of the socio-constructivist perspective, the previous sections have discussed Vygotsky's socio-historical theory and some of the other models, theories and instructional interventions that have since been derived from his work. Vygotsky's constructs of mediation and ZDP have provided the basis for most of the research on collaborative learning and have had substantial influence on education over the last thirty years. Combined with the work of Piaget, Bruner and the numerous researchers who continued their work, no one can deny now the role of collaboration to promote learning. Coming from different traditions, the studies discussed share a common commitment to the importance of collaborative learning and to its investigation.

The issues and findings will serve as stepping-stones as we go on to explore other important constructs and theories necessary to understand the object of study. To this end, the next section will focus on conceptual change theories and science learning.

Conceptual Change and Science Learning

Over the last three decades, researchers from the cognitive science and instructional psychology fields have put a great deal of effort into studying science learning at different levels. One topic that is the subject of much research is conceptual understanding, which will be the object of this section on conceptual change and science learning.

Some of the earlier results in this domain have informed us that children from an early age develop a first understanding of the world that surrounds them from everyday experiences (Carey, 1985). These conceptions are helpful to answer everyday problems and for this reason, they can be hard to modify even when they are confronted with different but scientifically accurate conceptions of that same world. Since then, much research on science learning has focused on studying those initial conceptions of the world, often called misconceptions, and how they can be refined when they interfere with the veridical conceptions taught in school. In light of this, this section will review some of the issues surrounding misconceptions and conceptual change that have emerged from research efforts so far. A first goal for this review of the literature was to identify the characteristics of conceptual change in elementary school science. Another goal was to identify effective ways to promote conceptual change in authentic classroom settings. However, working on this review has brought us to reconsider these initial goals. Indeed, the diversity of theoretical frameworks and methods used to study conceptual change has led to equal diversity in terms of characteristics of conceptual change. In fact, an enormous amount of work has led to detailed descriptions of misconceptions about various topics like acceleration and velocity (diSessa, 1982; Roschelle, 1991;White, 1983), the shape of the earth (Vosniadou & Brewer, 1992), naïve biology (Carey, 1985), circulatory system (Chi, 2005), electricity (Magnusson, Templin, & Boyle, 1997) and linear functions (Chiu, Kessel, Moschkovich, & Muñoz-Nuñez, 2001) just to name a few. This work has led to a general acknowledgment that misconceptions are robust because they persist in spite of direct instruction and that generally, conceptual change is hard to accomplish in traditional instructional contexts.

In parallel, authors from different perspectives have developed theoretical frameworks that attempt to explain conceptual change and misconceptions from which we cannot derive common characteristics to define the cognitive processes at play (Carey, 1985; Chi, Slotta, & deLeeuw, 1994; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Roschelle, 1992; Smith, diSessa, & Roschelle, 1993; Vosniadou, 1994) . The question thus becomes, depending on each theoretical framework, what are the characteristics of conceptual change in science? And accordingly, which framework will better inform this study? This will be the topic of the following sections.

Because it is sufficiently explicit yet general enough to encompass various interpretations, we shall use Schnotz, Vosniadou and Carretero's (1999) definition of conceptual change. However some nuances will emerge as we explore the different lines of work on this topic. Schnotz et al. (1999) define conceptual change as the reorganization of existing knowledge referred to when common sense understandings of children, actively constructed from everyday experiences, are incompatible with the knowledge they are being taught in school (Schnotz et al., 1999, p. xiii). This definition of conceptual change is consistent with a constructivist perspective on learning because it implies that children are not perceived as "blank slates" when they come to school. Indeed, it assumes that children, from a very early age, develop their own understanding of the world, based on everyday experiences with natural phenomena. However, when they come to school, some of these conceptions are not compatible with the scientific explanations being taught. The process by which they will come to adjust their conceptions to the scientific conceptions is what is generally called conceptual change.

To this day, there is no consensus on the actual definition of conceptual change. There also seem to be various takes on the nature of conceptual change, as well as on the nature of the process of conceptual change itself. Indeed, some authors discuss conceptual change as the process of replacing one conception for another (Posner et al., 1982; Vosniadou, 1999), others believe the existing concepts are refined rather than replaced by new ones (Smith et al., 1993). Moreover, some authors believe conceptual change happens in a sudden shift (Chi et al., 1994) whereas others believe it is a gradual process (diSessa, 1993).

Historically, research on conceptual change has its roots in two different traditions: developmental psychology and science education. The first line of work on conceptual change followed Piaget's work on cognitive development. This approach emerged from a need to reconcile Piagetian constructivism with findings that show, on the one hand, that children were more cognitively capable than Piaget thought and, on the other, that initial cognitive structures go through radical transformation through development (Vosniadou, 1999, p. 5). Developmental psychologists like Carey (1985) started working on conceptual change to find an alternative explanation to Piaget' position. Research later branched out into two research agendas, the first of which focused on the validity (or lack thereof) of conceptual change as a theory of learning and the second on the process of conceptual change through development and acquisition of expertise (e.g., Chi et al., 1994; Vosniadou, 1994; Vosniadou & Brewer, 1992) (Vosniadou, 1999).

The second line of work on conceptual change came from science education research and focused on naïve conceptions of domain-specific knowledge, also called misconceptions or alternative frameworks of reference. Work by Posner and colleagues (Posner et al., 1982; Strike & Posner, 1985, 1992) led to the development of a theoretical framework that has influenced in a major way instructional practices but that has since been the subject of important criticism (e.g., Pintrich et al., 1993). The following sections will further discuss each tradition's contribution to conceptual change research. From this review, one theory emerged as being the most appropriate to inform this research and it will be discussed last.

The Global Restructurings Theory

Research on conceptual change was first initiated in reaction to Piaget's developmental theory. Carey (1985) argued that contrary to the Piagetian explanation of cognitive development, a child's restructuring from his naïve theory-like conceptions to new theories was the result of his increased knowledge of the domain instead of the result of his context-independent logical capabilities. Before that, developmental psychologists believed that cognitive development was a process of "global restructurings", i.e., changes in the structure of thought occurred via the child's logical operations and that these changes constrained the child's abilities to reason and acquire knowledge in all domains (Vosniadou, 1999).

According to Carey, the shift from novice to expert implies the restructuring of knowledge as well as acquisition of additional knowledge, production rules, etc. Carey's restructuring refers to two things: (a) (weak) restructuring that implies different relations between concepts (e.g., from 'no motion without force' to 'no acceleration without force'), and (b) (strong) restructuring that involves patterns among these relationships that motivate the creation of new, abstract concepts and schemata that either are not represented by novices or not very accessible to them (p. 3). Carey associates weak restructuring to novice-expert research like Chi, Glaser and Rees' work (1982) and strong restructuring to Kuhn's (1970) and Lakatos' (1970) positions on scientific progress and theory change. According to Carey, the presence versus the absence of conceptual change is the essential difference between the two types of restructuring. Another important aspect of Carey's work is her emphasis on domain-specific knowledge. This emphasis is supported by evidence from novice-expert research (e.g., Chi et al., 1982; Ericsson, Krampe, & Tesch-Römer, 1993).

Carey's work on children's misconceptions about biology led the way to numerous efforts to describe misconceptions in a variety of scientific domains such as acceleration and velocity (diSessa, 1982; Roschelle, 1991; White, 1983), the shape of the earth (Vosniadou & Brewer, 1992), naïve biology (Carey, 1985), circulatory system (Chi, 2005), electricity (Magnusson et al., 1997) and linear functions (Chiu et al., 2001) mentioned earlier, but also on diffusion (Chi, 2005), naïve conceptions of force (Minstrell, 1984; Minstrell & Stimpson, 1986), and force and motion (Clement, 1982).

The Synthetic Model

Building on Carey's work, Vosniadou's position (1994) is that children's initial conceptions about the physical world can be thought of as a framework (or synthetic) theory of physics that is informed by their experience of the real world and on which can be constructed further knowledge. While this framework may facilitate knowledge acquisition, it may also hinder it, particularly in the case of learning science.

> In order to explain why science concepts are difficult to learn and misconceptions happen, we must assume that initial conceptual structures are supported by an interrelated system of observations, beliefs and presuppositions that form a relatively coherent and systematic explanatory system, which works relatively well in the everyday world and is rather difficult to change. (Vosniadou, 1999, p. 8)

Vosniadou and Brewer (1992) distinguish between beliefs based on superficial observations (and so, easy to change) and presuppositions that are deeper conceptual constructs (and more difficult to change). Vosniadou (1999) argues that this distinction is crucial in explaining why some students' misconceptions are more difficult to change than others.

Phenomenological Primitives and Knowledge System Framework

DiSessa (1993) proposes instead a theoretical framework based on phenomenological primitives (p-prims), elements of knowledge that form intuitive conceptions. Accordingly, misconceptions happen when these p-prims are associated to describe a situation but when the association does not form a coherent system. There are analogies to be made between diSessa and Vosniadou's positions; however, as Vosniadou states it herself (1999), the difference between the two theoretical frameworks is that diSessa's position argues that the p-prims do not form a coherent explanatory structure and that this lack of structure explains the difference between novices and experts while her own framework claims that a coherent initial explanatory structure does indeed exist, but that it is fundamentally different from the scientifically accurate one.

In a different paper, Smith, diSessa and Roschelle (1993) disagree with the traditional view that considers misconceptions as mistakes that hinder learning rather than as prior knowledge from which students construct their scientific understanding. More consistent with a constructivist perspective on learning, diSessa and colleagues' position claims that novice and expert conceptions are more alike than usually acknowledged in expertise research. The authors argue that most of conceptual change research so far has concentrated on describing different misconceptions across domains but in doing so, has implicitly embraced, if not explicitly, the notion of knowledge *replacement* rather than knowledge *refinement*. Knowledge replacement conflicts with the constructivist assumption that learning is the process of adapting prior knowledge. Smith and colleagues argue that adopting a constructivist perspective on learning implies the rejection of a theory of conceptual change that involves replacing the students' misconceptions by the experts' veridical conceptions. Instead, "if concepts are more like complex structures of related ideas than separable independent units, then replacement looks less plausible as a learning process (diSessa, 1993; Smith, 1992)" (Smith et al., 1993, p. 125). Consequently, Vosniadou's restructuring framework implies knowledge replacement, i.e., replacing the existing alternative conception by a scientifically accurate one.

Instead, Smith et al. (1993) propose a theory of conceptual change insisting on the continuities between novice and expert conceptions as stepping-stones of gradual conceptual change. The authors suggest that misconceptions have their roots in productive and effective knowledge and refuse to insist solely on how they differ from expert conceptions. The key to understanding how they may be productive and effective in certain occasions and not in others is the *context* in which they are used. They claim that most research on misconceptions so far have focused on analyzing situations in which these conceptions are ineffective and have neglected to examine closely the situations in which they are effective. To support their claim, they looked at misconception research analyses of novice and expert conceptions, but from their own constructivist view. When examining the usual distinctions being made between novice and expert conceptions (surface vs deep structure of problem, concrete vs abstract reasoning, etc.), the authors argue that

> novices in reasoning about the physical world: 1) seek deeper explanations of the causality involved in situations than are *immediately and superficially apparent*; 2) attend extremely selectively to features of situations, ignoring (abstracting from) many surface structures to focus on what they consider causally relevant; 3) apply principles that (a) apply hypothetically to a given situation, (b) are intended to identify underlying causal mechanisms (deep structure), and (c) may be withdrawn under consideration of other arguments. (Smith et al., 1993, p. 131, emphasis added)

The authors insist on the need to define more elaborate models of knowledge that include different knowledge components of various grain sizes. A more complex, systems view of knowledge may provide a more powerful framework to understand learning, in a constructivist perspective. According to this view, "understanding the strength of a particular conception will depend on a characterization of the knowledge systems that embeds that element" (Smith et al., 1993, p. 152). A complex system of knowledge elements may evolve gradually from naïve to more expert-like conceptions, naïve conceptions no longer considered as entirely flawed but effective and useful depending on the context. Consequently, they predict that "if the view that everyday experience is refined and reused in scientific thinking is correct, we should find some use of everyday ideas in the reasoning of experts" (Smith et al., 1993, p. 139) and proceed to verify this by reanalyzing an example of expert reasoning. This analysis revealed that it might be more productive to study the role of naïve physical concepts in expert reasoning than to suggest that the main issue of developing expertise lies in replacing old conceptions by new ones (p. 145).

Many authors have since built on Smith et al.'s view of conceptual change. Chiu and colleagues (2001) have discussed students' conceptions and strategies when learning to graph linear functions. Although these authors believe there can be both refinement and replacement processes involved in conceptual change, their study showed instances where conceptual change occurred through refinement. Consistent with Smith et al.'s position (1993), Chiu et al.'s case study "suggests that students can refine their strategies by specifying their contexts of applicability, extending their uses, and by making connections among conceptions" (p. 245). Magnusson and colleagues (1997) have also built from this work and proposed a sociocultural view of cognition: Dynamic Science Assessment (DSA) that aims at identifying the potential of conceptual change the students show. Their position assumes that conceptual change is a gradual process, that the initial conceptions form incomplete systems and that instruction should lead to a gradual development of scientifically accurate conceptions.

The Ontological Categorization Theory

Chi and colleagues (1994) presented their own theory of conceptual change to explain why some kinds of conceptual change are more difficult than others. This theory addresses the way knowledge is structured cognitively. It assumes that entities in the world belong to different ontological categories, such as MATTER[2], PROCESSES and MENTAL STATES. The authors claim that many scientific concepts (e.g., light) belong to subcategories of PROCESSES, which they call constraint-based interactions. While students do come to class with conceptions about the world, some of these conceptions may be ontologically compatible or incompatible with the veridical conceptions. For example, students' initial conception of light may be categorized as MATTER while the veridical conception is conceptualized as PROCESS. This incompatible categorization of light as the students' initial conception is what is called a misconception. The authors claim that conceptual change occurs when a concept is re-assigned from one ontological category to another (Chi et al., 1994). In short, "re-assigning a concept from its initial tree onto another tree is the crux of our notion of conceptual change" (p. 29). According to this theory, learning science concepts is difficult because it requires conceptual change across trees.

The rest of the article is particularly interesting because the authors clearly state their incompatibility hypothesis in light of their proposed theory and proceed in examining evidence to support it. Indeed, Chi (1992) reviewed the literature on misconceptions and confirmed in doing so the general prediction about the ease of learning ontologically compatible concepts and the difficulty of learning ontologically incompatible concepts. The authors predicted that when the concepts to be learned are ontologically incompatible with the students' initial conceptions, the naïve conceptions should tend to be robust, consistent, persistent,

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[2] These authors adopt the use of capital letters for the primary ontological categories that are referred to as 'trees'. I follow these conventions to discuss this theory in order to facilitate comprehension.

homogeneous and recapitulated[3]. Conversely, when the concepts to be learned are ontologically compatible with the students' initial conceptions, they should tend to fit the opposite pattern.

To further confirm their incompatibility hypothesis, Chi and colleagues adopted an expertise approach and designed an experiment that analyzed the use of MATTER-based and PROCESS-based predicates by 10 novices and four experts for physics concept and material substance problems[4]. Evidence to support this theory was provided by this experiment: naïve conceptions of physics concepts were MATTER-based, implying that a shift in ontological category was needed for them to achieve conceptual understanding, novices did not use the PROCESS-based predicates of these concepts and experts maintained a distinct category for these concepts that were consistent with a subcategory of PROCESSES.

Critics of this theory include Vosniadou (1999) who argued that the restructuring referred to by Chi et al. (1994) was what she considered weak restructuring, and not strong restructuring, her own definition of conceptual change. Vosniadou's position assumes conceptual change as a gradual process whilst Chi's position would assume a sudden shift. Furthermore, she critiqued

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[3] "(a) "robust," meaning that students hold onto their initial beliefs firmly, so that they are difficult to overcome by instruction, confrontation, or any other mode of challenge; (b) "consistent" over time and situations, meaning that the same misconception is displayed by the same student over different times and across different contexts; (c) "persistent" across different ages and schooling levels, such that college students, high school and elementary school children all maintain more-or-less the same sort of misconception (i.e., there is no developmental trend); (d) "homogeneous" among different students (i.e., different students in either the same or different studies display similar misconceptions); (e) "recapitulated" across historical periods (i.e., the medieval scientists and contemporary naive students tend to hold the same misconceptions)" (Chi et al., 1994, p. 35).

[4] One example of a problem used involved electrical current in a closed circuit and the material substance isomorph was the case of a water faucet supplying a series of sprinklers along a hose.

Chi's choice of categories, and claimed there was not enough evidence to account for them.

In a recent paper, Chi (2005) revisits her early ideas about conceptual change. She claims that "miscategorization of processes-as-substances" cannot account for students' misconceptions about diffusion. This realization had for effect a reevaluation of her prior work on conceptual change over the last decade.

> The main point of these early ideas, that students miscategorize certain science concepts as substances rather than processes, do not offer a complete account for concepts such as diffusion, for surely students know that diffusion is a process. Recall that students do in fact think of diffusion as a process of flow in which entities (such as dye liquid) move from one location to another. Therefore, a simple argument based on miscategorization of processes-as-substance is insufficient to explain the kind of misconceptions described in diffusion. But can we salvage the notion of ontological miscategorization to account for misconceptions? The nature of diffusion and circulation, as described above, can be taken to represent two different, perhaps ontologically distinct, kinds of processes: emergent and direct. Therefore, instead of misconceiving of processes-as-substance, perhaps students are misconceiving of emergent-as-a-direct kind of processes. (Chi, 2005, p.188)

This constitutes a crucial shift from her prior work since she moves from a domain-specific view to a domain-general view of conceptual change. Chi states that the conceptualizations and explanations that she now proposes are comprehensive but that they are incomplete in many ways. Concluding her paper, Chi presents the limitations of this new model and calls for further empirical evidence to support it.

Chi et al.'s (1994) original ontological theory of conceptual change is quite convincing. It not only provided a theoretical framework supported by the authors' research findings, but it also was one of the few frameworks that could explain previous research findings on misconceptions. Furthermore, unlike most other theories and models, it stated a clear hypothesis and predictions later tested against empirical findings. Although it provided a strictly cognitive account of conceptual change without accounting for the social processes, this theory was nonetheless very interesting. However, Chi's recent paper (2005) presents counterarguments that cannot be ignored. There is still much work to be done to support the new hypothesis of a domain-general explanation of conceptual change. For this reason, using this theory to inform our study would be too risky but we believe that great attention should be paid to Chi's future work on conceptual change.

The Epistemological Framework Theory

The second line of research on conceptual change comes from instructional theory and focuses on how to replace naïve conceptions of domain-specific knowledge. Posner and colleagues (1982) developed the most salient theory of conceptual change from this perspective. They proposed a general model of conceptual change largely inspired from philosophy of science. According to this view, there are two phases of conceptual change in science. First, research is organized according to a set of central commitments (paradigms for Kuhn,1970; theoretical hard cores for Lakatos,1970). In the second phase, those central commitments need to be revised or modified (Kuhn's scientific revolution; Lakatos' program shift). According to these authors, there are analogous patterns of conceptual change in learning. *Assimilation*[5] is the first phase of conceptual change, i.e., when learners use existing conceptions to deal

[5] Although the authors acknowledge the use of Piaget's words, they insist it should not be taken as a commitment to his theories (Posner et al., 1982, p. 219, footnote)

with new phenomena. The second phase, *accommodation*, is when the existing conception cannot successfully deal with the new phenomena and a new conception is needed: the learner must reorganize his concepts or replace[6] them. According to this theory, a central concept will come to be replaced under certain conditions, namely

> 1) there must be dissatisfaction with the existing conceptions, 2) a new conception must be intelligible, 3) a new conception must appear initially plausible, and 4) a new conception should suggest the possibility of a fruitful research program. (Posner et al., 1982, p. 214)

Posner and colleagues also proposed the idea of a "conceptual ecology" formed of concepts that govern conceptual change. A series of features[7] of this conceptual ecology influence the selection of a new central concept. In short, their model explains how the conditions of conceptual change relate to the conceptual ecology and account for difficulties students face when they are learning science.

This theoretical framework led to the development of numerous instructional uses of "cognitive conflicts" to promote conceptual change. Unfortunately, empirical evidence has failed to show the actual effect of cognitive conflicts because they often do not lead to conceptual change (e.g., Champagne, Gunstone, & Klopfer, 1985; Dreyfus, Jungwirth, & Eliovitch, 1990; Schnotz et al., 1999). Research has shown that instead of being replaced, naïve conceptions are often maintained and manage to co-exist beside the new, veridical conceptions.

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[6] Despite diSessa's position about knowledge *replacement*, Posner and colleagues argue that this view acknowledges the importance of prior knowledge.

[7] These features are: 1) anomalies, 2) analogies and metaphors, 3) epistemological commitments (i.e., explanatory ideals, general views about the character of knowledge), 4) metaphysical beliefs and concepts, and 5) other knowledge (i.e., knowledge in other fields and competing concepts) (Posner et al., 1982, p. 214-215).

> Students learn to master the scientific vocabulary, learn to reproduce the knowledge taught in school and to answer the teachers' questions but outside school, they continue to use their old conceptions, while their know knowledge remains "inert" [Collins et al., 1989]. (Schnotz et al. 1999, p. xiv)

However, Posner and colleagues (1982) argued that the accommodation process as it is presented in their model should not be oversimplified nor understood as being a straightforward process. In fact, the authors believed that conceptual change would more likely be a "process of taking an initial step toward a new conception by accepting some of its claims and then gradually modifying other ideas, as they more fully realize the meaning and implication of these new commitments" (p. 223).

An often-cited critique of Posner et al.'s epistemological model comes from Pintrich and colleagues (1993). They argued that this model put too much emphasis on the "cold" cognitive processes and ignored the affective and motivational factors that are an integral part of learning. In direct contradiction with Pintrich and colleagues, diSessa argued that, contrary to his own model of conceptual change, Posner and colleagues' model does not say anything about the actual cognitive processes involved but rather describes the instructional context that should be in place to promote conceptual change.

Beyond Cold Conceptual Change

Pintrich and colleagues (1993) presented an analysis of Posner et al.'s (1982) model of conceptual change and argued that it was overly rational. They highlighted the theoretical difficulties of a model that does not take into account the motivational factors that are goals, values, self-efficacy and control beliefs as additional mediators of the conceptual change process. According to these authors, Posner et al.'s (1982) model should also have taken into account the role of classroom context and motivational factors in the process of learning. One of their argument concerns the analogy being made between progress in the scientific community and conceptual change in the classroom, also called the "child as scientist" metaphor. Pintrich et al. (1993) assume that, contrary to this metaphor, the classroom community does not operate in the same fashion as the scientific community but is influenced by personal, motivational, social and historical factors. Furthermore, these authors believe that while scientific progress may be influenced by these "irrational" factors, the ultimate acceptance of content is strictly determined by empirical and logical factors.

Another critique has to do with Posner and colleagues' metaphor of conceptual ecology. The first assumption implied by this metaphor is a systemic assumption, i.e., that concepts are organized in a system and changes in one concept are going to influence the whole network of concepts. According to Pintrich et al. (1993), this system view of learning implies the influence of many forces on whether conceptual change may happen or not. The second assumption of this metaphor has to do with epistemological beliefs about the nature of knowledge. These will impact the individual's conceptual ecology by deciding what is or is not a valid explanation as new experiences and knowledge are raised in an effort to promote conceptual change (p. 171). Thirdly, the authors claim that there is a possibility of different ideas, competing for the same conceptual niche, which would be particularly important in the case of accommodation. In such a case, the "surviving" ideas would be the ones that successfully resolve anomalies and that conform to the individual's epistemological beliefs. Here is where the authors think the conceptual ecology metaphor falls short.

> Ecosystems are not purposeful, but individual learners and communities of scholars can and do have goals, purposes and intentions, thereby suggesting a role for an individual's motivational beliefs. It is not clear how competing ideas in a purposeful ecosystem of the mind might behave differently from organisms and populations in a biological system. (Pintrich et al., 1993, p. 172)

In spite of this, the authors admit that the conditions needed for conceptual change proposed in the Posner et al. (1982) model are interesting if conceptual change is considered as an entirely rational cognitive process. But they argue that evidence to the contrary is abundant in the literature. They support their claim with evidence from research done on motivational beliefs but also from research on peer and teacher interactions.

Pintrich et al.'s (1993) general claim is that besides being influenced by motivational factors, the conceptual change process may be influenced by the contextual factors of the classroom as well as the interactions between students and teacher. Caravita and Halldén (1994) also argued for the situated nature of cognition and its place in the conceptual change process. Finally, another critique of this model of conceptual change has to do with the paradoxical role of prior knowledge in conceptual change. According to Pintrich et al.,

> a paradox exists for the learner; on the one hand, current conceptions potentially constitute momentum that resists conceptual change, but they also provide frameworks that the learner can use to interpret and understand new, potentially conflicting information. (1993, p. 170)

This was also a part of Smith et al.'s (1993) critique because they believed the proposed model of conceptual change was based on replacement rather than refinement of prior conceptions. However, in the original paper (Posner et al.,

1982) the authors argue "that inquiry and learning occur against the background of the learners' current concepts" (p. 212).

Pintrich et al.'s paper (1993) was a reaction to Posner et al.'s position and it denounced its lack of consideration of the affective as well as the social factors in learning, and consequently, on conceptual change. At the same moment, a Strike and Posner chapter (1992) agreed with some of those critiques and offered some nuances on their earlier position. Among other things, Strike and Posner agreed with the need to take into account a wider range of factors in attempting to describe a learners' conceptual ecology and to include the current scientific conceptions and misconceptions as interacting parts of this conceptual ecology. They also called for a diverse mode of representation for conceptions and misconceptions. Finally, the authors called for a developmental view of conceptual ecologies. To this day, Posner et al.'s model seems less favored as recent reviews like Mayer's commentary (2002) on theoretical views on conceptual change fail to even mention it. This is perhaps the clearest sign that the gap between science education research and cognitive science research on this matter has yet to be bridged.

By this time, the influence of Vygotsky's (1978, 1986) theory of learning as well as applied cognitive science research consistent with this perspective were also insisting on the influence of social and cultural factors on learning and conceptual change (e.g., Brown, Collins, & Duguid, 1989; Caravita & Halldén, 1994; Lave & Wenger, 1991; Roschelle, 1992). Ivarsson, Schoultz and Säljö (2002) took a radical stance and argued that social processes are not merely *involved* in conceptual change but they are in fact central to the whole process.

Their view of conceptual change places society as the sole venue for conceptual change and tools such as language, signs and symbols as mediators between the individuals and their culture. According to Mayer (2002), if this view adopted a social constructivist rather than radical constructivist perspective, then it would be reconcilable with other views that recognize the role of individual cognitive processes. For now, the different views differ according to the mechanisms of conceptual change they assume and by the different methods used to study them rather than on testable theories and empirical data. Accordingly, challenges still lie at the theoretical and methodological levels.

The Convergent Conceptual Change Model

In light of the different theoretical frameworks that we have described and discussed above, this section now turns to Roschelle's model of convergent conceptual change (1992). Roschelle's goal was to construct an integrated approach to collaboration and conceptual change. In this case study, Roschelle used a conversational analysis approach to account for conceptual change happening during a collaborative problem solving activity. The central claim is that the crux of collaboration is the problem of convergence: "how can two (or more) people construct shared meanings for conversations, concepts and experiences?" (p. 235).

With that in mind, the author analyzed two students exploring physics concepts collaboratively. He proposed that a process described by four primary features could account for convergent conceptual change in a collaborative context. This process of convergent conceptual change came from the integration of research on scientific collaboration and conversational analysis (CA) on convergence of meaning in everyday situations (Roschelle, 1992).

> The four primary features [of this process] are: 1) The construction of a "deep-featured" situation at an intermediate level of abstraction from the literal features of the world, 2) the interplay of metaphors in relation to each other and to the constructed situation, 3) an iterative cycle of displaying, confirming, and repairing situated actions, and 4) the application of progressively higher standards of evidence for convergence. (p. 237)

The first two features of this process describe the nature of the students' conceptual change: use of metaphors and interaction between them and the deep-featured situation constructed to understand a phenomenon. The latter two features describe the mechanisms of convergence that enable the social construction of concepts. This analysis is quite different from previous analyses of conceptual change because it considers the social aspect of conceptual change through a convergence of meaning lens, "convergent conceptual change is achieved incrementally, interactively and socially through collaborative participation in joint activity" (p. 238).

To support this claim, the paper includes a case study of two high school science students engaged in discovery learning to solve a series of physics problems on the effect of acceleration on velocity. In short, they work with a computer simulation[8] to construct a correct understanding of acceleration. In order to support the proposed convergent conceptual change process, the author predicts two outcome claims: (a) that the students will construct collaboratively an understanding of acceleration that constitutes a conceptual change from their initial understanding, and (b) that the students will share this new understanding.

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[8] The Envisioning Machine (Roschelle, 1991)

Roschelle also predicts one process claim, i.e., the four-step convergent conceptual change process that we have previously described.

A conversational analysis of the students' interaction during one series of episodes during the intervention provides strong evidence of two kinds: cognitive outcomes i.e., that conceptual change did occur, and social outcomes, i.e., that both students shared the new conceptual structure as a result of their collaboration. The evidence presented in this article also supports the two outcome claims (i.e., that conceptual change occurred and that individual interpretations converged toward shared knowledge) as well as the process claim. The author illustrates how the four features of the process were observed in the students' collaborative process.

Consistent with their constructivist argument on the role of prior knowledge in conceptual change, Smith et al. (1993) had argued for a systems perspective on knowledge, which is a first important asumption about conceptual change that underlies Roschelle's model. This perspective is consistent with other explanations of conceptual change as a gradual process rather than a sudden shift (Mayer, 2002; Smith et al., 1993; Strike & Posner, 1992;Vosniadou, 1999, 2002). Regarding the actual structure of knowledge, his position follows diSessa's (1993) knowledge-in-pieces or "p-prims" model of conceptual structures and this is reflected by the students' use of metaphors to construct the shared deep-featured construct. In line with diSessa's emphasis on the role of prior knowledge as a vehicle rather than as an obstacle to conceptual change, Roschelle uses the students' metaphors (pull, hinge, travel) as prior conceptions that interact to inform their common understanding of a new phenomenon.

Argument in Favor of Roschelle's Model

The above sections presented a comprehensive review of the major theoretical frameworks that exist on conceptual change to this day. Although this review of theories on conceptual change initially aimed at studies conducted in elementary school science, some of the work discussed above was done with older students (middle and high school). They have been included to provide a more general idea of the different theories and models that have been proposed so far.

Overall, one theoretical framework appears to offer the most explanatory power for the present study, namely Roschelle's (1992) convergent conceptual change model, which builds on diSessa's theory of knowledge-in-pieces and collaborative work on knowledge systems framework (Smith et al., 1993). This model appears to provide the most explanatory power for the present work for the following reasons.

First, it acknowledges the role of individual cognitive processes in conceptual change while at the same time accounts for the social processes that are involved in collaborative learning. Roschelle not only situates the cognitive activity in a social context but also shows how the social aspect of the context accounts for cognitive processes in both students' mind. Furthermore, the methodology used to describe the mechanisms of convergent conceptual change is consistent with Vygotsky's emphasis on the role of language in the development of higher processes (1978, 1986).

Second, Roschelle's model builds from diSessa's (1993) p-prim model of conceptual change. This model is truly constructivist as it places great emphasis on the role of prior knowledge. It claims that there is a lot to learn from naïve conceptions and this fits with a constructivist perspective on learning. DiSessa's knowledge-in-pieces model is also consistent with Smith et al.'s (1993) systems of knowledge perspective. This view assumes that knowledge may take various forms and should be understood as a complex system rather than as simple cognitive structures, as also assumes the dynamic science assessment methodology proposed by Magnusson et al. (1997).

Third, Roschelle's view puts forward the importance of situated learning. To this end, Roschelle studied conceptual change in an authentic situated and collaborative context, mediated by the computer simulation but also by the students' own utterances and actions. The use of conversational analysis principles to account for convergent conceptual change is consistent with the present research context, which will include writing as the primary mode of communication between students of remote locations. Some attention will be put on the differences that written speech may bring to the actual situation under study but Roschelle's model is still the most appropriate on this matter.

Finally, Roschelle's emphasis on the role of mediation in conceptual change is another aspect of his model that is particularly relevant. In fact, the particular classroom learning context of this study will not only be mediated by the peers and the teacher, but also by a computer tool, as it will be discussed in the third part of this chapter. For this reason, a model that puts mediation at the forefront such as the one described by Roschelle is highly relevant to the study of conceptual change in authentic classroom contexts.

These reasons support our decision to adopt Roschelle's convergent conceptual change model to inform this study. Consistent with Roschelle, we will also adopt diSessa's knowledge-in-pieces theoretical framework for conceptual change and consequently, Smith et al.'s knowledge as systems model (1993). We believe that this framework should provide the theoretical grounds needed to analyze this object of study and should help to describe if and how computer-supported collaborative inquiries can promote conceptual change in science at the elementary school level.

The third part of this chapter will review some of the major findings and issues in science education research at the elementary school level. It will also briefly address two Canadian science education curricula. This should provide insight into the current state of the field of science education, with a particular focus on collaborative problem solving and inquiry.

Collaborative Problem Solving and Inquiry

In the recent years, efforts have been geared toward engaging students in inquiry-related activities and projects as an effective means to learn science (American Association for the Advancement of Science [AAAS] 1994; National Research Council [NRC], 1996). This emphasis on inquiry-based science relies on the fact that science is a question-driven, open-ended process that students should experience personally in order to fully understand the nature of science. Inquiry can provide an authentic context in which investigation procedures and scientific concepts and skills can be discovered, applied, questioned and verified. Scientific inquiry approaches often focus on the scientific process leading to the solution or explanation, as much as on the solution itself. Students would benefit from engaging in some kind of cognitive apprenticeship in science (Brown et al., 1989), during which they are able to learn the ideas and cultural tools of science, and gradually join the community of scientists, through legitimate peripheral participation (Lave & Wenger, 1991).

With that in mind, a review of exemplary practices was conducted to identify the main issues and findings of collaborative problem solving in elementary school science. Included were studies of educational practices in line with the major principles issued from cognitive research such as being (a) knowledge-centered, (b) inquiry-based, and (c) student-centered (see American Psychological Association [APA], 1993; Bransford, Brown, & Cocking, 2000; Bruer, 1993). Other factors were considered for inclusion such as the importance of the research program, the evidence of learning outcomes generated by empirical evidence and research methodologies consistent with our research perspective, such as the study of discourse. Furthermore, studies that were conducted in computer-supported collaborative learning contexts were closely examined.

Judging from the articles reviewed, their findings but also the issues raised, and because they emerged as being the most relevant to inform the research questions, it appears that engaging students in scientific inquiry requires that particular attention be given to: (a) scaffolding the students' inquiry process, (b) supporting the collaborative conversation, (c) using explanation-based activities to promote deeper understanding, and (d) exploring the role of abstract representations in science learning. Other findings will also be discussed as they also inform our reflection. Finally, the science curriculum itself will shortly be addressed.

Scaffolding the Inquiry Process

Ann Brown's work in the Fostering Communities of Learners (FCL) research program discussed earlier is generally considered among the exemplary practices in science education. Guided discovery describes a learning process that builds from Dewey's discovery learning but without its pending lacunas, notably through careful teacher guidance of the students' inquiry process. The key activities of guided discovery are (a) independent and group research on a topic of inquiry, (b) to share information, (c) in order to perform a consequential task demanding that all students have learned everything about the topic. "The community relies on the fact that the participants are trying to understand deep disciplinary content" (Brown, 1997, p. 404). Teachers in guided discovery act as facilitators, guiding the learning experience of the students, being aware of student understanding and their zone of proximal development (ZPD, Vygotsky, 1978; Bruner, 1960, 1987). Brown and Campione (1994) acknowledge the fact that it is hard to do but claim that it does get easier with time. FCL, as other reform efforts, needs time. The success of the FCL program is significant on many levels. Students in the experimental group score significantly higher than control students on content knowledge tests, transfer tests, reading comprehension scores in other domains, production of analogy in discourse as well as production of explanation in the spontaneous discourse (see Brown & Campione, 1994). However, some weaknesses have also been identified including teacher competence and their role as critical-thinking models. Indeed, the role of guide in the discovery process itself is difficult to maintain and constantly requires judgment on whether and how to intervene or not. Also, because students are apprentice learners, the teacher is expected to model scientific inquiry in thought as well as in action. Not surprisingly, it requires the expertise of gifted teachers.

Krajcik, Blumenfeld, Marx, Bass, Fredricks and Soloway (1998) studied project-based science at the middle school level. Investigating how students deal with a first experience of inquiry learning, the authors discovered that they were able to design investigations and plan procedures but lacked the ability to identify good research questions and showed weaknesses in gathering and interpreting data to draw conclusions from. They stressed the importance of helping students to understand the distinction between theory and prediction. A year later, Herrenkohl, Palincsar, deWater and Kawasaki's (1999) discussed the role and value of scaffolding student discussions to help them develop their ability at co-constructing theories and models from data collected while investigating floating and sinking. Particular attention was paid to helping students distinguish theory from prediction through consecutive discussions. The use of specific roles that the students played in both their own experiments and their peers' helped them monitor their own thinking process (see also Palincsar & Herrenkohl, 2002). This study showed that elementary school students' notions of theorizing evolved over time and reached a level of sophistication that is often unsuspected from students that young thus suggesting that they can reach such a level with sufficient modeling, scaffolding and teacher guidance. Focus on the distinction between theory and predictions in this study echo the findings and issues raised by Krajcik and colleagues (1998).

In a recent study, McNeill, Lizotte, Krajcik and Marx (2006) studied the effect of continuous versus fading written instructional support (scaffolds) on students' capacity to develop explanations of scientific phenomena when they were no longer provided with the support. Their results showed that both treatments generated learning gains for students for all components of scientific explanation (i.e.,, claim, evidence, and reasoning). However, fading written scaffolds proved to better help students to write explanations as the faded group generated richer explanations than the continuous group when they were not provided with the support.

Also interested in scaffolding the students' inquiry process, White, Shimoda and Frederiksen (1999) designed a software called SCI-WISE that acts as a community of interacting agents who each have expertise in accomplishing high-level goals. The agents give advice to the students as they reflect on their inquiry process. This work builds on the creation of the ThinkerTools Inquiry Curriculum (White, 1993; White et al., 1999), which engages students in inquiry and scaffolds their work with a generic inquiry cycle that provides a model of the inquiry process. This cycle is made explicit to students and is presented as a sequence of goals to be pursued: (a) question, (b) hypothesize, (c) investigate, (d) model and (e) evaluate. SCI-WISE was designed to support metacognitive skills of inquiry. This line of research is consistent with prior work on reasoning which indicates that children's performance on reasoning tasks is significantly affected by their ability to coordinate hypotheses and evidence (Klahr, Fay, & Dunbar, 1993; Kuhn, Amsel, & O'Loughlin, 1988; Schauble, 1996, cited in Palincsar 1998). Also of interest is Metz's (2004) study of the concept of uncertainty in science. Her study showed that with adequate scaffolding, most children could develop a rich understanding of how uncertainty is a part of scientific inquiry.

Using Explanations to Promote Understanding

A different line of research studies the potential of collaborative explanations to promote conceptual understanding in science (Coleman, 1998). Instructions and procedural prompts require students to explain, justify, evaluate, compare and contrast their personal knowledge with scientific knowledge. Coleman studied whether this explanation-based intervention could promote students deep understanding of photosynthesis. Results show that average intentional learning student explanations resembled those of high intentional learning students: their explanations were conceptually more advanced than the average control students. They also acquired and retained more subject knowledge than the control group. This is consistent with Hatano and Inagaki's (1987) results that students who are required to defend, elaborate and explain their ideas evaluate, elaborate and integrate knowledge in new ways (Roth, McGinn, Woszczyna, & Boutonné, 1999). Hakkarainen's (2003b) analysis also indicates that in order to be successful, activities should be explicitly designed to encourage students to develop theories and explanations about phenomena so that they can engage in authentic activities to make sense of the world.

Supporting the Collaborative Conversation

In her review of social constructivist perspectives on teaching and learning, Palincsar (1998) points to the beneficial role of instructional conversation. Palincsar points specifically to the fact that interpretive talk (i.e., generated for the purpose of analysis or explanations) is associated with more significant learning gains that descriptive talk, a view shared by Wegerif and Mercer (1996, 1997). Furthermore, the effectiveness of classroom discourse is closely related to teachers' mediation of this discourse. The teachers' role in pushing the students to further their thinking and discussion is central. Palincsar also points to the importance of attending the structure of group activity so that expertise is distributed across the members of the group, responsibility is shared and the overall classroom "ethos" supports building on each others' ideas (p. 365).

Brown's FCL program, Scardamalia and Bereiter's (1999) knowledge building pedagogy as well as Cobb, Wood and Yackel (1991) talk about the importance of a classroom culture that supports scientific inquiry and that should aim to resemble a scientific community. Cobb et al. (1991) specifically explored the analogies between a scientific community and a second-grade math classroom. Their work revealed how the teacher created a learning environment in which children were called to validate each other's ideas, explained personal solutions to others, listening to each others' explanations and attempted to achieve consensus. This study revealed that after five months, these classroom norms were in place and required less guidance by the teacher.

Barron's (2000) attempt to characterize between-participant interaction differences and collective accomplishments led her to identify three major dimensions in group interaction: (a) mutuality of exchanges, (b) shared task alignment, and (c) degree of joint attention in solution-critical moments (p. 432). Even though this study was about elementary math, these dimensions of group interaction can still inform science learning as it points to dimensions of collaborative work that are not domain-specific.

A year later, Mason (2001) published the results of a naturalistic inquiry that investigated the introduction of talk and writing as a tool for conceptual change in a 4th grade science classroom. As they progressed through four curriculum units on decay, the students used talk for learning in small and larger group discussions as well as individual writing for learning. The results show that reasoning and arguing collaboratively as well as individual writing to express, clarify, reflect and reason on and communicate conceptions and explanations of a scientific phenomena such as decay were fruitful in the knowledge revision process. These studies stress the importance of supporting the collaborative conversation in order for such interaction to lead to deep understanding.

Abstract Representations and Collaboration

Schwartz (1995) studied dyads and abstract representations with high school students. This article reported the highly significant results from three studies that indicate that, in order to coordinate their respective representations, students working in dyads formed abstract representations while students working individually rarely did. Recall that Roschelle (1992) pointed to the role of an intermediate conception that the students used to discuss their conceptual understanding of acceleration. Like Schwartz, Roschelle pointed to the need to converge ideas, or representations, in order for students to collaboratively solve a problem in science. Collaboration provided an opportunity for students to develop abstractions (Schwartz, 1995) and in turn, the use of abstract representations helped students reach convergence (Roschelle, 1992).

Other Findings in Science Education

Other research programs in science education include community-based science in urban settings, (Bouillon & Gomez, 2001), participating structures and their impact on scientific discourse (Hogan, Nastasi, & Pressley, 1999; Hogan, 1999; Roth et al., 1999), instructional strategies for inquiry and tools (Edelson et al., 1999), and productive disciplinary engagement in communities of learners (Engle & Conant, 2002). Marx, Blumenfeld, Kracjik, Fishman, Soloway, Geier et al. (2004) have reported findings from the use of curriculum materials developed collaboratively by the University of Michigan and Detroit Public Schools. Their goal is to demonstrate that student achievement can be attained when the focus of a reform is highly specified and materials to support it developed accordingly. The results for now show an effect size that is low but constant and while it is too soon to confirm that the effects are to be attributed to treatment only, the importance of this research program demands future attention.

Science Curricula and International Assessment

Planning a classroom research project also implies taking into consideration the curriculum and, when possible, the performance level of the actual student population in worldwide assessments. To this end, a brief look at the 2006 PISA[9] results indicated that Canadian students scored rather highly on this assessment (Government of Canada website, n.d.). Particularly, Alberta scores in science were the highest of all other canadian provinces, followed by British Columbia and Ontario. Quebec scores came in fourth place, with scores equal to the Canadian mean which is lower than the previous PISA results (2003) where Quebec was second to Alberta.

[9] The PISA is the OECD Programme for International Student Assessment. It is a three-yearly survey (2000, 2003, 2006...) of 15-year-olds in the principal industrialized countries and it assesses mathematics, reading, science problem solving knowledge and skills (see http://www.pisa.oecd.org for more details).

A comparison of the two curricula in elementary school shows that the Albertan curriculum emphasizes the role of inquiry in science learning as well as problem solving with technology (Alberta Government website, n.d.). The new Quebec science curriculum is more focused on the adoption of a competency approach and identifies the core competencies and knowledge (Ministère de l'Éducation du Québec [MEQ], 2001). Although a project-based approach is often associated with the new program in the media and the general population, no particular instructional strategy is explicitly stated in the curriculum which might explain some of the resistances to adopt the program as heard in the media. The key features of the competencies, the evaluation criteria and the essential knowledge elements are clearly stated but the ways and means to do it are not. In doing so, we believe that the Ministère de l'Éducation, du Loisir et du Sport [MELS] (formally MEQ) acknowledges that teaching requires autonomy, creativity and professional expertise.

In parallel, some authors have critiqued the level of detail of the Albertan curriculum stating that it is in fact disenabling teachers to adopt genuine inquiry-based approach because it is too prescriptive (Rowell & Ebbers, 2004). Meanwhile, the Quebec government is considering giving teaching permits to graduate students from various disciplines who have no pedagogical training if they commit to complete some pedagogical training units over an agreed period of time. This decision will probably confound the PISA results for some time and will certainly not help the reform movement as it is not very consistent with recognizing teachers as professionals in due form. However, curriculum is but one of many factors of science education in Canada and should only be taken as such.

In addition to the issues related to misconceptions and conceptual change discussed previously, this review of research on collaborative inquiry in elementary school science has underlined what should prove to be key aspects of the learning context of this study. Among them, the importance of scaffolding the inquiry process has emerged as being central to deep science learning. The findings also point to the necessity to better support the collaborative conversation. Research on explanation-driven activities indicates that it can lead to deep understanding and confirms the need to expect students to explain scientific phenomena and not only describe it. Furthermore, the role of abstraction in collaborative learning should be explored attentively, particularly as it relates back to conceptual change according to Roschelle's model. Generally, these findings point, but not surprisingly so, to the crucial role of mediation in collaborative inquiry, whether it refers to the teacher, the peers or the use of computer tools in classrooms. These mediating factors will be discussed in more detail in the final part of this chapter.

Teachers, Peers and Computer as Mediating Factors

As we discussed in the first part of this chapter, one auxiliary hypothesis of Vygostky's theory of learning that is particularly promising is the role of mediation in the ZPD. What do we know about the nature of interactions in this ZPD? What is the role of different mediating factors on learning in a particular context? The following addresses the role of mediating factors, i.e., teacher, peers, and computer tool, and more specifically the case of Knowledge Forum as a knowledge-building tool to support collaborative inquiry in science.

At the classroom level, the teacher's role as mediator includes putting forward the conditions and means necessary for the activation of his students' higher processes. The teacher's role as mediator implies picking up on the students' interests and recognizing topics that interest them, encourage students' engagement in their learning, and foster deep understanding. It also implies creating ZPDs and guiding learners through them, scaffolding their learning process, insisting on a specific concept that is difficult to grasp, letting go of others until they are ready to understand them. In science, as we have discussed earlier, one issue raised is how to effectively scaffold students' inquiry process.

Scaffolding the Learning Process

According to Clancey (1995), scaffolding is a dynamic process that involves the self-regulation of one's own actions and talk (for example, an expert) according to the other's actions and talk (for example, a novice) to explicitly bring the novice to develop his ability at performing a task. Rogoff (1998) describes scaffolding this way:

> [...] the subtle and tacit skills of determining a learner's current state of understanding and designing a supportive situation for advancement have been observed in parent-infant interaction, both verbal and non-verbal, and in interaction in tutoring sessions by adults working with children or other adults. In all these situations, interactional cues – the timing of turns, nonverbal cues and what each person says or does not say- are essential to the partner's achievement of a challenging and supportive structure for learning that adjusts to the partners' change in understanding. (p. 704)

In Collins et al.'s (1989) cognitive apprenticeship model, "[scaffolding] is the support, in the form of reminders and help, that the apprentice requires to approximate the execution of the entire composite of skills" (p. 456). The interplay between observation, scaffolding and increasing independent practice helps the learner to develop self-monitoring skills as well as develop his conceptual understanding and integrate the necessary skills to reach expertise (p. 456).

Scaffolding is one of the major roles of the teacher in the inquiry process, a role that is closely linked to expertise as a teacher. However, prompts and cognitive tools can be introduced in the learning environment to help scaffold the learner's progress. They can be used to break up the task and reduce the learner's information-processing burden. The students can use them to scaffold their own thinking process or that of their peers. The careful integration of a computer tool like Knowledge Forum to mediate student activity through written discourse can also provide additional support to student learning. Consequently, scaffolding ceases to be the teachers' sole responsibility and can be shared with the students, using tools and artifacts that help them take on a difficult task. The following sections examine how each of these mediating factors can support the learning process.

Teacher as Mediating Factor

To get their students to actively engage in constructing their understanding of science, teachers are encouraged to adopt an inquiry approach and emphasize scientific reasoning and explanation-oriented activities, as we have previously discussed. Children need a great deal of pedagogical and epistemological guidance in order for them to engage in genuine processes of inquiry, as discussed by Hakkarainen and colleagues, (Brown & Campione, 1994; Hakkarainen, 2003a, 2003b, 2004; Hakkarainen, Lipponen, & Järvelä, 2002) among others. They cannot do it alone. In this sense, the teacher's role, not surprisingly, is crucial.

Some studies have attempted to provide new strategies to facilitate teacher mediation in scientific inquiry (e.g., Hunt and Minstrell's (1994) work with students' facets; Polman and Pea's (2001) transformative communication). The authors recognize certain limits to their program, notably the time it requires, social acceptance of the technique and the reliance on teacher's experience with student conceptions. Again, a limit to those strategies is the high reliance on the teacher's own understanding of scientific inquiry and the development of a culture of inquiry in the classroom and schooling in general. "To facilitate higher-level practices of inquiry in elementary-level education, a substantial epistemological change in pedagogy and in the wider culture of schooling is needed" (Hakkarainen, 2003b, p. 1086),

A major characteristic of Magnusson et al.'s (1997) DSA is to assess student knowledge in the context of mediated learning situations that aim to lead to conceptual change. In this study, the authors conceptualize teacher mediation in science education into three dimensions: (a) metacognitive mediation, i.e., helping students to develop self-monitoring skills, (b) domain-specific reasoning mediation, i.e., helping students to recognize and adopt the general standards of the scientific community, and (c) mediation with respect to domain-specific ideas, i.e., focusing students on the central concepts of a discipline.

Another line of research has to do with providing cognitive tools specific to inquiry and that can be used both by the teacher and the students. For example, Herrenkohl et al. (1999) have found that the children's notion of theorizing evolved due to significant scaffolding by the teacher, as well as the use of cognitive tools and roles and the nature of the activity itself. In this study, a major contribution to the students' conceptual understanding of scientific reasoning was due to the teacher-guided discussions on the meaning of theories. The carefully guided discussions, scaffolded by the use of cognitive tools and roles integrated in the inquiry process supported the students' conceptual understanding significantly. The use of the cognitive tools supported the students' work but also the teacher's intervention. White et al. (1999) have done similar work with the ThinkerTools curriculum and later with the SCI-WISE software. Even in the case of activities involving computer tools that offer various scaffolding features, the role of teachers as mediating factors is still central. Although the environment is different from regular face-to-face conversation, the teacher's role in guiding the students' inquiry process is similar. However, the computer may provide different affordances to support student learning. We will discuss these affordances later but it can be assumed that the preceding dimensions of teacher mediation in the classroom should also be reflected in the teacher's online mediation.

Hakkarainen (2003a, 2003b, 2004) and Veermans, Lallimo and Hakkarainen (2005) provide further evidence of the impact of teacher mediation on learning with the Knowledge Forum. Hakkarainen (2003b) underscores the importance of the teacher's epistemology when showing that in order to facilitate higher-level practices of inquiry in elementary classrooms, the teacher must encourage students to engage in explanation-processes of inquiry, to generate hypotheses and theories, even if they may be mistaken. Hakkarainen's work points to the role of the classroom culture in supporting student-driven inquiry as discussed in other work (Bielaczyc & Collins, 1999; Brown, 1997; Brown &

Campione, 1994). A culture of inquiry does not emerge by itself in a classroom but must be intentionally designed and cultivated.

Teacher mediation in the context of inquiry is closely related to their own understanding of inquiry and their ability at managing complex inquiry instruction in their classrooms. Windschitl (2003) reported that while

> inquiry is the quintessential experience of science,[...]the vast majority of preservice science teachers enter their preparation programs without having conducted a single inquiry in which they have developed a question of interest and designed the investigation to answer that question .(p. 113)

Windschitl's (2003) multi case study highlighted the importance of authentic inquiry experiences to account for the teachers' integration of inquiry in their eventual practice as science teachers. Indeed, the student teachers who later integrated inquiry in their classroom practice were the same who reported having experienced authentic inquiry prior to their education program. The other teachers preferred direct instruction and *confirmation* experiences in which students verify known scientific principles by following a given procedure (Windschitl, 2003, p. 114). We can infer from this work that this may very well be the case in this study. The teacher's role in mediating student activity in this learning context is thus central.

Peer Mediation

Another important mediating factor in classrooms is the presence of peers and their role in student learning. We have discussed in the first part of this paper how higher mental processes are related to the social and cultural environment. Naturally, the social and cultural environment of a classroom is highly bound to its members, the teacher and the students, which participate in many joint activities mediated by classroom discourse. Whether it is written or not, classroom discourse is one of the major manifestations of classroom activity and ultimately learning. Classroom discussions require that student organize, articulate and share their knowledge of a topic, that they listen to one another, confront ideas and build from each other a common understanding. Engaging students in a discussion about science provides the opportunity for them to deepen their understanding and identify areas of uncertainty, as well as to learn how to reason and organize their ideas in ways that are consistent with scientific activity. In this sense, the role of peers in mediating student activity is another important aspect of collaborative learning. This role can be investigated through the analysis of classroom discourse.

Hogan and colleagues (Hogan, 1999; Hogan et al., 1999) studied student discourse and scientific reasoning in a Grade 8 science class constructing a conceptual model of matter from incomplete ideas. They found that the teacher-guided discussions were more efficient (i.e., needing fewer turns to achieve acceptable solution) in terms of generating higher levels of reasoning and higher quality explanations than student-guided discussions. However, the student-guided discussions did have merit in being more generative and elaborated. Teachers tended to push students to provide explanations whereas students' interactions tended to generate justifications for their ideas.

This is consistent with Rogoff's (1998) comprehensive chapter on cognition as a collaborative process, in which she reported that children as teachers focused more on the completion of the task rather than making sure their partner understood the rationale. The peer-tutor either did too little (gave no explanation at all) or too much (took over the task themselves). However, she reported that " peers were less likely to explain their strategies or talk-aloud their decisions than were adults, and they were less likely to share in joint decision making in skilled planning" (p. 709). Her paper also stressed the idea that decision-making occurring jointly with the exploration of different perspectives among peers contributes to children's progress in understanding (p. 711). Rogoff noted that the literature on peer argumentation was not coherent enough to allow conclusions about the important aspects of peer argumentation but mutual engagement with each other's thinking appears to be central (p. 713).

However different, Rogoff treats the role of peers and adults (of different status and expertise) as complementary resources in cognitive development through collaboration, insisting on the importance of shared thinking in the collaborative problem solving process. Rogoff suggests that adults are not necessarily in a position of authority and children not necessarily in a position of equality hence the importance of considering patterns of interaction that involve peers and adults as joint contributors to children's learning. "Collaboration can take many forms, the key feature being that people are involved in others' thinking processes through shared endeavors " (p. 728).

Knowledge Forum as Mediating Factor

Another mediating factor in the learning environment of this study is a particular computer tool. Much research has investigated computers in schools over the last fifteen years. One line of research investigates the use of computer simulations to support science learning (e.g., Lajoie's BioWorld (1993), Pea's CoVis Project (1993), Roschelle's envisioning machine (1991), to name a few).

Another important line of research studies the role of computers to support collaborative learning. Lehtinen et al.'s (1999) review of empirical studies on the role of computer-supported collaborative learning (CSCL) has shown that CSCL environments support higher order social interactions which results in better learning in terms of conceptual understanding, metacognitive knowledge, skills and changed beliefs and attitudes. Among the tools reviewed was the particular case of Computer Supported Intentional Learning Environments (CSILE) project (see Scardamalia, 2004). Knowledge Forum (KF), the commercial name of CSILE, is the knowledge-building tool that will be used in this study.

Designed to support intentional learning, Knowledge Forum has many features that distinguish it from other collaborative tools. It is an electronic forum that offers additional capabilities such as the use of annotations[10], rise-above notes[11] as well as search tools, the use of keywords and the possibility for the authors to revise and continuously improve their notes. Shared authorship of the notes is another feature of Knowledge Forum that contributes to support knowledge building. Notes are identified with a problem as well as a title and scaffold supports are available to support the writing process. For example, when using the scaffold support *My theory*, students must be aware of what a theory is, and if it is indeed a theory they want to contribute to the database. These scaffolds can be used as prompts as well as metacognitive tools. The scaffold supports may also be customized so that a teacher can define his own set of prompts and use it

[10] Annotations can be used to comment on a note without it being a direct contribution to the collective discussion around a topic.

[11] Rise-above notes can be to sum up the ideas of a particular discussion-thread to bring the discussion a step further.

to support the development of metacognitive skills in any domain he may want to explore using Knowledge Forum. In the case of a science problem, for example, a teacher can use customizable prompts to support the students' inquiry process. These technological features provide distinctive affordances (Allaire, 2006) that may be used to mediate the collaborative inquiry process.

Knowledge Building

A key notion behind the development of Knowledge Forum is the notion of knowledge building. Building from the work of new approaches that conceptualize classrooms as scientific research teams in which students engage in inquiry-based activities similar to the genuine scientific culture (e.g., Brown & Campione, 1994; Collins et al., 1989), Scardamalia and Bereiter (1999) have called for a transformation of schools into knowledge building organizations. The crux of their argument for supporting a knowledge building pedagogy is that schools need to change from service organizations to knowledge organizations. Just like scientific teams, schools as knowledge organizations imply that the goal is to produce knowledge. "The individual and collective learning that goes on within the group is secondary – a byproduct of knowledge production and a contributor to it" (Scardamalia & Bereiter, 1999). The rationale behind this model is to focus on getting students engaged in genuine construction of knowledge.

These authors stress the importance of creating learning environments that call for authentic knowledge building i.e., creating opportunities in which children are asked to solve genuine knowledge problems. "The task of an elementary school class that takes a knowledge building approach is to construct an understanding of the world as they know it" (Scardamalia & Bereiter, 1999).

Several empirical studies have investigated the effects of CSILE/Knowledge Forum on student learning. Scardamalia, Bereiter and Lamon (1994) discussed the results of seven studies. The assessment of CSILE effects was composed of seven different qualitative and quantitative studies that were aimed to assess students' "shift toward mastery goals and away from performance goals, and evidence of deeper understanding" (p. 211) (what the authors call World 2 effects) as well as "improved knowledge quality and evidence of constructive activity in students' collective work" (p. 211) (what the authors call World 3). Among other results, the authors have found that CSILE students showed greater ability to construct deeper explanations than non-CSILE students. They also produced more advanced explanations and diagrams that contained more causal and dynamic information. CSILE students provided deeper explanations of their own work, which constitutes as evidence of greater metacognitive skills. CSILE students were better at resolving analogous situations and when working on a Jasper series problem, they made a higher proportion of references to higher-level goals.

Chan, Burtis and Bereiter (1997) studied how peers and individuals process scientific information that contradicts with what they know and how this may relate to conceptual change. This high school study led to the identification of two approaches: (a) direct assimilation of the new information with existing knowledge and (b) knowledge building, i.e., treating the information as problematic that needs to be explained. They have found that cognitive conflict may trigger knowledge-building activity, which in turn may lead to conceptual change, but they believe that without knowledge building, cognitive conflict would not lead to conceptual change.

Chan, Lam and van Aalst (2003) studied high school students' conceptual understanding of organic chemistry, the characteristics of the students' knowledge building discourse and the relations between the students' knowledge building actions and discourse and their conceptual understanding. Also, database usage was related to qualitative discourse in the portfolio and both were correlated with gains in conceptual understanding. The authors claim that the knowledge-building environment may have fostered both individual and collective knowledge advances. Significant correlations among gains on conceptual understanding provide additional support suggesting that students' engagement in database usage and discourse might be beneficial to their conceptual understanding (Chan et al., 2003).

Etheris and Tan (2004) explored computer-supported collaborative problem solving and anchored instruction in a mathematical classroom (grade 6). These authors used customized scaffolds to help the treatment group in their problem solving process. The dependent measures were the students' problem solving performance and their attitudes towards mathematics. Results show that the students' attitudes towards mathematics were generally favourable and that students who solved the problem in the scaffolded environment tend to perform better than those using the un-scaffolded environment.

Hakkarainen (2003a) reported the emergence of a culture of inquiry over the course of a three-year study in two Canadian and one Finnish CSILE classrooms. His study confirmed that students could be guided to engage in a process of inquiry in which they approach problems in deepening levels of explanations. He examined CSILE students' knowledge production by analyzing the nature of research questions produced as well as the explanatory level of scientific and intuitive knowledge processed (Hakkarainen et al., 2002). The five explanatory levels of knowledge ranged from 1 (*isolated facts*) to 5 (*explanation*) (see examples in Hakkarainen et al., 2002, p. 137-8). The results of Hakkarainen's studies indicated that with guidance, students using Knowledge Forum (or CSILE) could engage in deep-level inquiry (Hakkarainen, 2003a), and were able to generate their own intuitive theories and search for explanatory scientific information to answer their research questions (Hakkarainen, 2004). The results show that there were significant differences between the groups regarding the epistemological nature of the knowledge productions. Discussing the two Canadian classrooms, Hakkarainen attributed these differences to the epistemological nature of the learning tasks.

> It was characteristic of Classroom A to conduct conceptually-challenging study projects that focused on gaining theoretical understanding of the problems being investigated, whereas Classroom B's study projects focused on acquiring factual knowledge and empirical generalizations that usually did not go beyond everyday phenomena. It was typical for Classroom B projects to guide students to examine differences and similarities between biological phenomena (e.g., species, habitats) being investigated. (Hakkarainen, 2003a, p. 217)

Hakkarainen (2003a) stressed that the differences between the three groups were closely bound to the teachers' epistemology. According to the author, the Classroom A teacher apparently showed signs of "expansive learning (Engeström,

1987) in which the teacher, with support, reflected on practices of his classroom culture, identified weaknesses and tensions of prevailing practices, and searched for novel opportunities to be pursued in the subsequent year"(p. 218). Hakkarainen's results (Hakkarainen 2003a; 2003b; 2004) provide further evidence of the crucial role of teacher mediation in the students' collaborative inquiry process, even when advanced computer tools support them.

The importance of teacher mediation in collaborative knowledge building supported by Knowledge Forum was also supported by Veermans et al.'s (2005) study, which examined student guidance as well as in Messina, Reeve, and Scardamalia's (2003) study of collaborative structures supporting knowledge building. Lipponen's (2000) study of student discourse also supports these findings. The author identified three different types of discourse: social-oriented, fact-oriented and explanation-oriented. Not surprisingly, the students' discourse was predominantly fact-oriented rather than explanation-oriented.

> This pattern of discourse seems to be deeply rooted in current practices of teaching and learning (Cazden, 1988; Lampert, 1990). As a result, it cannot be expected to change or to be changed easily, but presupposes a long process of exploring and testing different cognitive and pedagogical practices. (Lipponen, 2000, p. 192)

The preceding empirical results on the use of Knowledge Forum to support collaborative learning, and especially those related to science learning, have confirmed once more the importance of the teachers' mediating role. Although the computer tool itself does provide distinctive affordances that can mediate student learning in this environment, whether through the use of particular scaffolds of the inquiry process or because it provides a powerful discourse medium, the teacher is still mostly responsible for the epistemological nature of the learning tasks of his classroom. The teacher also provides the collaborative structures to support or not effective peer interaction.

This chapter has allowed us to critically review the literatures and define the appropriate theoretical and conceptual frameworks necessary relevant to this object of study, namely, collaborative problem solving in science at the elementary school level, supported by a particular computer tool, with a specific interest for the socio-cognitive processes of conceptual change. While the chapter was broken down into four parts, it is understood that the issues addressed are highly interwoven and do not exist in isolation.

The first part of this chapter discussed Vygotsky's socio-historical theory of learning and how it influenced education research over the last decades. At the classroom level, this theoretical perspective explains why collaborative work is so important in learning and suggests paying particular attention to how collaboration is supported to promote deeper learning. The second part of this chapter explored the different theoretical frameworks associated with misconceptions and conceptual change research, an important issue in science education. Roschelle's (1992) convergent conceptual change framework emerged as the best framework to inform a classroom study on this topic. The third part of this chapter consisted of a review of exemplary practices in collaborative problem solving and inquiry in science. This review has pointed to the fact that fruitful scientific inquiry-based learning requires that particular attention should be given to: (a) scaffolding the students' inquiry process, (b) supporting the collaborative conversation, and (c) using explanation-based activities to promote deeper understanding. The fourth part of this paper explored how different mediating factors, such as teachers, peers and computer tools, specifically Knowledge Forum, can impact the learning process in a collaborative scientific inquiry environment. Overall, the teachers' role in establishing a classroom culture that promotes conceptually challenging projects rather than factual knowledge-based inquiry is central. It is not surprising to expect this will also be the case in this study.

Research Questions and Hypotheses

In light of the conceptual and theoretical framework, the research questions and hypotheses addressed in this study are:

As elementary school students collaborate online to solve problems and conduct inquiries in science,

1. How can the use of prompts (i.e., scaffold supports) to support the inquiry process in class and online help students better understand and put into practice an inquiry process, individually and collectively?

The first underlying hypothesis is that using the Knowledge Forum to share and socially construct their theories and predictions, their observations of the phenomena studied in class and to discuss collaboratively online what they perceive as relationships between the said theories and predictions and the results of their observations, students will develop an authentic and deeper understanding of the inquiry process. This should better enable students to put the inquiry process into practice to resolve science problems and conduct collaborative inquiries.

2. How does the students' online collaborative problem solving translate into a deeper understanding of the phenomena explored?

The second underlying hypothesis is that as students develop their capacity to adopt an inquiry process and a deeper understanding of each subprocess (e.g., theorize, predict, observe, relate) they should improve their capacity at developing theories to explain phenomena, at making predictions based on these theories and at observing the phenomena with those theories and predictions in mind, consequently developing attitudes and aptitudes that resemble that of expert scientists. In other words, students should show increased capacity to solve problems and conduct inquiries in science.

3. Can this particular collaborative problem solving context lead to conceptual change? If so, what are the characteristics of students' conceptual change in this learning context?

The third underlying hypothesis is that as students become more comfortable with the idea of sharing and constructing their ideas about scientific phenomena with their peers, there should be more opportunities for them to communicate their representations and conceptions of different phenomena. This in turn should provide new opportunities for teachers to be aware of the students' prior knowledge and initial conceptions, as they will be expressed through student discourse in the classroom but also on the Knowledge Forum. Expressing these initial conceptions should provide new opportunities for the teachers to address them and to support conceptual change when needed. The collaborative nature of the problem solving activities could also provide opportunities for students to engage in convergent conceptual change as they collaborate to achieve a common understanding on the studied phenomenon.

Accordingly, as it builds on Roschelle's (1992) work, this study will look for instances of collaborative conceptual change that may share some of Roschelle's convergent conceptual change process features: (a) the construction of an intermediate level of abstraction, (b) the interplay of metaphors in relation to each other and to the constructed situation, (c) an iterative cycle of displaying, confirming, and repairing the situated action, and (d) the application of progressively higher standards for evidence for convergence.

For the purpose of this doctoral dissertation, we believe that the investigation of the research questions and hypotheses presented above should provide the field of applied cognitive science with a better understanding of some of the sociocognitive processes involved when students from remote locations collaborate to solve problems in science, using a technology tool such as Knowledge Forum. We also believe that this study will generate new knowledge on the role of the teacher in enriching the learning and problem solving situations in a classroom that uses collaborative tools and activities to promote deeper understanding in science.

CHAPTER 2 — METHODOLOGY

Context of Study

Remote Networked Schools Initiative

Since September 2002, the *Remote Networked Schools/École éloignée en réseau* (RNS) initiative investigates the conditions for the use of information and communication technologies (ICTs) as a viable solution to the problem of the accessibility and quality of elementary and secondary school education in the remote regions of Quebec. Now closing its Phase III (2006-2008), the RNS initiative has involved 13 (now 22) school boards since 2004 and over 50 schools. Researchers from three Quebec universities are involved in RNS: Université Laval, Université du Québec à Chicoutimi (UQÀC), and McGill University. The participants of this study are all currently engaged in the RNS initiative.

Design Experiment

Generally, this research project builds on Brown's design experiment (DE) research (Brown 1992, 1997; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Design experiment research intends to inform practice. Accordingly, it takes into consideration the constraints of average classrooms, which are built around average students and teachers, with average and realistic technological and personal support (Brown, 1992, p.143). Brown (1997) also supported the importance of doing both design experiments and controlled studies. Embedded in the overall RNS design experiment, this particular study proceeded with more controlled analyses addressing a set of precise questions on collaborative problem solving in science, in the particular context of RNS.

Furthermore, the use of a design experiment approach offers a context enabling teachers and researchers to harmonize their conceptions of scientific inquiry. Starting from simple scientific experiments, we hope to develop iterative designs around increasingly complex inquiry activities showing a progressively greater degree of complexity in the questions students ask and attempt to answer and deeper understanding of the underlying phenomena. As such, this design experiment also provides a professional development opportunity for the participating teachers as the principal investigator actively participates in the negotiation of a harmonized conception of inquiry and how it can be successfully transposed in carefully scaffolded classroom practices in a learning context such as this one.

The use of fairly traditional pre-test and post-test data combined with in-depth discourse analyses of some students or groups of students allowed us to get a sense of the effect in terms of specific outcome measures but also to gain a greater understanding of the phenomenon. Challenges associated with design experiments include coordinating multiple levels of analysis and the interventionist nature of the methodology. In such studies, the researcher is not a passive observer but an active participant in the design and the actual unfolding of the investigated activities. Also distinctive of design experiment research is the iterative nature of the design. As the activities unfold and the participants reflect on their practice (Schön, 1983), results and observations are shared with the teachers and reinvested in the classroom practices. As such, design experiments combine cycles of invention and revision, the intended outcome of which is "an explanatory framework that specifies expectations that become the focus of investigation in the next cycle of inquiry" (Cobb et al., 2003, p.10).

In this study, the goal was to develop with the different sites iterative designs to improve the quality of their collaborative efforts. In the case of collaborative inquiries, this had for objective to help students gain a deeper understanding of the explored phenomena. In doing so, we also hoped to generate opportunities to explore evidence of collaborative problem solving and convergent conceptual change while participating in the development of new RNS practices.

Participants

The participants of this research project consist of three dyads, i.e., two classrooms working together, both classrooms of the dyad being in different primary schools of the same school board. In all, three sites (i.e., school boards) will be involved. Sites A, B and C (uppercase) each consist of two collaborating Cycle 3 (grades 5-6) classrooms (except A3b which includes one grade 4 student). The groups (i.e., classrooms) identified with a lowercase "a" are the groups from the pilot schools, and the groups identified by a lowercase "b" are the groups from partner schools within RNS. Pilot schools were specifically designated by the school board to become a RNS; partner schools were chosen in the same school board as potential partners for RNS activities. As such, pilot schools are usually much smaller, with multi-level classrooms, lower performance levels and from populations of lower SES than their partner schools. For the sake of simplicity, we shall henceforward refer to each group as A3a, A3b, B3a , B3b, C3a and C3b. Table 1 briefly describes each group.

Table 1

Participants of this Study

		Site A	Site B	Site C
Group a Pilot school	Group	A3a	B3a	C3a
	Grade	Cycle 3 (Grades 5-6)	Cycle 3 (Grades 5-6)	Cycle 3 (Grades 5-6)
	Number of students	24	15	21
	SES level	Low	Low	Medium
	Teacher	30 yo female (first half of the year) 23 yo female (other half) 1rst year teaching	35 yo female 13 years teaching	50 yo female 27 years teaching
Group b Partner school	Group	A3b	B3b	C3b
	Grade	Cycle 2/3 (Grades 4-5-6)	Cycle 3 (Grades 5-6)	Cycle 3 (Grades 5-6)
	Number of students	5	24	21
	SES level	Low	High	Low
	Teacher	39 yo male 17 years teaching	34 yo female 13 years teaching	42 yo female 10 years teaching

Prior to being solicited to participate in this research project, the teachers were identified as potential candidates for the following reasons. First, these three RNS sites were the first to show signs of the presence of Ely's eight conditions that facilitate the implementation of educational technology innovations (1999): 1) dissatisfaction with status quo, 2) knowledge and skills required, 3) availability of resources, 4) availability of time, 5) rewards and incentives, 6) participation in decision-making process, 7) commitment to change, and 8) leadership. According to Ely, the presence of these conditions facilitates the adoption of innovative pedagogical practices such as the ones consistent with the new Quebec curriculum, encouraged in RNS and consequently in this study (see Turcotte & Hamel, 2008). At the outset of Phase II (September 2004), these three sites had already put into place five out of 8 conditions. As the iterative research cycles progressed, these sites improved or maintained these conditions.

Second, the virtual ethnography of the RNS (Phase II) online activities has shown that these three sites have attained higher levels of integration of the videoconferencing tools in their daily practice, showing again a high level of work and effort into being a RNS. Third, the nature of the learning activities that have been taking place in these three sites so far have shown to be in line with Quebec's new curriculum and RNS objectives. These schools have shown increasing ability to engage students in authentic problem solving activities. Fourth, these schools have shown a high level of student online productivity compared to other RNS.

Last but not least, when asked if they wanted to participate in this study, the teachers themselves showed a great interest in this project either because they hoped it would help them progress towards even richer collaborative work with their students and/or because they expressed specific needs regarding science teaching and they felt this project could help them in their professional development. Also noteworthy is the fact that some of these teachers had already begun to reflect on their classroom practice using KF and had manifested interest in further developing their students' and their own use of the online tool to support their students' collaborative problem solving process.

Consequently, in May and June 2006, we met with each dyad in order to start planning the science activities for the upcoming school year. Two teachers were met online through videoconferencing because they were unable to travel to meet in person. During these meetings, the teachers and researcher negotiated some of the details of this design experiment: expectations from both sides in terms of participation were shared, teachers' ideas about the science activities they wished to do together were explored as well as how they could be supported online, etc. The teachers also identified a couple of themes from the Quebec science and technology curriculum they wished to work on in the coming year. The following is a general description of the type of classroom activities that are the object of this study.

Ethical Approval

The study was approved by the Research Ethics Board in compliance with the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (see Appendix K). The consent forms explained to the participants (students and teachers) the parameters of involvement in the study as well as rights to withdraw at any point without prejudice (see Appendix A and B).

Method

Procedures

A first activity was to introduce the students to a three-part inquiry process that very much resembles the one developed and studied by Palincsar and Herrenkohl (2002). Building from this work, we proposed a very simple inquiry process built around these actions: theorize, predict, observe, and relate. The terms could be subject to further negotiation with the participants but except one modification in Site A (they added the scaffold support "I would like to know"), and in site B (they added the scaffold support "My experiment") they remained quite close to this four-step process. During this activity, particular attention was paid to the distinction between theory and prediction, as suggested in Herrenkohl and colleagues (1999). Theories were presented as possible explanations for the phenomenon observed while predictions were presented as observations that were to be made in relation to the proposed theories. The activity consisted of a classroom discussion on science and on what is an inquiry process. Students were asked to share their ideas about science and what it consists of. A short pre-test was given on this topic prior to the discussion (test on inquiry process in Appendix C).

Students were then asked to think of a theory and a related prediction on a specific topic or phenomena chosen by the teachers usually from inquiry-based didactic materials (e.g., What floats? What sinks?). This launched the first science activity conducted in class. Students discussed among themselves before writing a note on the Knowledge Forum while others chose to log on right away. In doing so, students started learning how to use the corresponding scaffold supports, customized to fit with the inquiry process (e.g., *My theory*, *My prediction*, *I relate*, etc.) as they worked on the selected activity. The researcher was present on site during this activity.

During the school year, students explored different science phenomena. Each activity took place in roughly the same manner. When possible, students were first asked to fill out a pre-test on the corresponding theme (students were asked to try and explain the phenomenon they were about to investigate, see example in Appendix E). The second part of the activity consisted of the actual experiments[12]. Once students had conducted the experiments, they discussed in class and online, the relationships that exist between their theories and predictions developed collaboratively prior to the experiments, and how they relate to their actual observations. Following this, they were asked to improve and develop theories that could better explain their observations. Throughout, students were invited to share, construct and improve their theories, predictions and observations with their peers using the Knowledge Forum. The teachers and the researcher also contributed to the Knowledge Forum database to scaffold the inquiry process. When possible, once the teachers considered the activity over, students completed a short post-test on the topic. The short test was the same as the pre-test. At the end of the year, a post-test on the inquiry process was also be given out to students. Again, it was the same as the corresponding pre-test.

Data Collection

Dense and authentic data was collected for this study. The main part of the data collected was the students' notes on the Knowledge Forum database. Every student's notes on Knowledge Forum was automatically be saved in the database. Basic quantitative data on the use of the Knowledge Forum was computed using the Analytical Toolkit ([ATK], Burtis, 2001), which provided summary statistics of Knowledge Forum database activity. The ATK computes the number of notes written, the number of notes each author has created, which and how many scaffold supports are used, which views each author has working on, what

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[12] Marcel Thouin's book (1999), for example, includes many such experiments.

percentage of the notes have been read, whether or not build-ons (elaborations), keywords, references and other features were used, etc.

Aside from quantitative data collected on the database usage, the content of each note written was collected for discourse analysis at different grain sizes.

A pre- and post-test on the inquiry process was completed at the beginning and end of the school year (see Appendix C). Students were asked to say what they think theories and predictions are, what science is and why we conduct experiments in science. Each student answered these tests individually. Within subject effects were measured using pre- and post-test achievement scores on the inquiry process test.

Pre- and post-tests on specific concepts related to the inquiries conducted in class were also completed during the year in Sites A and C. For example, a test was completed before and after the activity on relative density and buoyancy in both sites (see Appendix E for the test and Appendix F for the rubric).

Additional data were obtained through videotaping of classroom activities when possible. This data provided evidence for a better understanding of the classroom culture and practices, specifically regarding the collaborative practices of each classroom. Video sequences were shot throughout the year to that intent. Even though the bulk of the data analyzed consisted of notes from the Knowledge Forum database, video footage provided additional information on the learning environment.

In addition, interviews with students and teachers at different times during the school year were videotaped. Field notes and online discussions with the participants were also part of the data set. Online work with the participating students and teachers was the norm rather than the exception throughout the school year, although presences on site happened periodically. Teachers and students were able to communicate online with the researcher on the Knowledge Forum, but also through email and desktop videoconferencing. Other artifacts were also included in the data collection if they provided further insight on the learning processes occurring in this study (e.g., emails, drawings, classroom exercise sheets, telephone conversations, etc.). Measures such as the grade and gender of each student were also included in the dataset.

Data Analysis

A mixed method approach to data analysis was adopted for this study, which consisted of quantitative as well qualitative analyses of the collected data.

Quantitative analyses. Group participation data were first analyzed (levels of participation across groups and sites, number of notes created across activities) to present an overall understanding of the participation rates across sites during the year. Statistical analyses were then conducted on individual student data to identify trends and significant differences between and within groups on various measures (note creation, scaffold use, coherence of scaffolds). Statistical analyses on the pre- and post-tests (test on the inquiry process, test on relative density and buoyancy) scores were also conducted.

Additional quantitative measures from the Knowledge Forum database were also generated and analyzed (number of questions asked and length of discussion threads).

Qualitative analyses. Since the bulk of the data consists of student interaction records, qualitative analyses were also conducted. In general, content analyses documented the individual and collective processes involved during the collaborative problem solving activities occurring on Knowledge Forum. For these analyses, the chosen methodological approaches were closer to Chi's (1997) verbal analysis' model than to Newell and Simon's (1972) protocol analysis. Indeed, this research was not meant to lead to a cognitive task analysis and the identification of a solution path through a determined problem space but rather to the representation of knowledge from ill-defined referents (see Chi, 1997). The use of mixed methods is another particularity of verbal analysis that is coherent with this study. Chi describes verbal analysis as an iterative process that aims to fit the data as much as possible (1997). The content analyses were conducted at different grain sizes but student *ideas* were the main units of analysis.

Content analyses were conducted to generate insight on the learning processes observed (e.g., coherent use of scaffold supports, nature of the questions and levels of explanation of the ideas expressed). Hakkarainen's (2003a, 2003b, 2004) work provided useful insight to this study since he conducted different analyses on data collected in the knowledge building context provided by CSILE/ Knowledge Forum. Hakkarainen's discourse analysis focused on the students' progressive discourse by analyzing the nature of research questions produced as well as the explanatory level of scientific and intuitive knowledge processed (Hakkarainen, 2003a, Hakkarainen et al., 2002). He created the Level of Explanation Scale used in this study to analyze student ideas according to a continuum ranging from 1(*separated, isolated facts*) to 5 (*explanation*). His model will be presented in detail in Chapter 3.

It seems important to point out that the type of discourse under analysis here falls at the intersection of "classic" dialogic classroom discourse (see Cazden, 2001; see also Lemke's Triadic Dialogue (1990), adapted from Sinclair and Coulthard's (initiation-response-feedback [IRF] sequence, 1975) and written discourse such as that produced in electronic discussion forums. Consequently, the situation under analysis in this study presented some characteristics of both types of discourses. Therefore, the specific methods used to study had to be suited to this particular context.

Some other models were considered: Hogan et al. (1999) for example, used various interactional analyses to study discourse and scientific reasoning in peer and teacher-guided group discussions. Kaartinen and Kumpulainen's (2002) framework to analyze the cognitive processes involved in collaborative inquiry was also considered although it had yet been used to study elementary school student discourse. Wegerif and Mercer (1996) distinguished three different types of talk: disputational, cumulative and exploratory. A fourth type of talk was introduced by RNS colleagues as Knowledge Building talk (see Hamel, 2007). Riel and Levin's (1990) work on participating structures in electronic communities also provided insight into how to understand and interpret the nature of the student discourse collected in this study. Weinberger and Fisher (2006) proposed a multi-dimensional approach to analyze argumentative knowledge construction in computer-supported collaborative learning (CSCL). His framework is based on four process dimensions particular to the context of CSCL: participation, epistemic, argumentative and social modes of interaction. After consideration however, Hakkarainen's Level of Explanation Scale was chosen for our analyses because it fit more closely with the collected data and it could better help us gather evidence to answer the research questions of this study.

Finally, specific discourse analyses were conducted where evidence of convergent conceptual change emerged (Roschelle, 1992). Verbal data from interviews and video sequences were used to further document the sociocognitive processes observed. These various data sources allowed triangulation of the data and thus, improved the reliability of the analysis.

CHAPTER 3 – RESULTS PART 1

Group Participation Data

During school year 2006-2007, the three participating sites engaged in computer-supported collaborative learning activities in science. Namely, they each selected and conducted collaboratively inquiry-based activities using online tools across schools. Table 2 presents an overview of data.

The participation data presented and discussed in the following sections give us a general idea of the various forms online collaborative activities may take in different contexts. Although the starting point for each site was the same, it was not expected to unfold in the same ways everywhere. The following comparisons between sites and groups do not attempt to verify any hypothesis at this point but only serve to illustrate the various forms and participation rates such activities may generate in six authentic classroom contexts.

Table 2

Overview of Data

	Site A	Site B	Site C
Activity 1			
Length of activity	6 weeks	13 weeks	17 weeks
Topic of inquiry	Pollution-generating machines, renewable and non-renewable energies	Permeability and impermeability of material	Rocks and minerals
Participants (number of students; number of adults)	(29;2)	(39;4)	(42;3)

Notes created	61	81	42
Participation level [13]	100%	80%	100%
Activity 2			
Length of activity	5 weeks	3 weeks	4 weeks
Topic of inquiry	Acid-base solutions	Skeleton and bones	Buoyancy and relative density
Participants (number of students; number of adults)	(29;3)	(39;2)	(42;2)
Notes created	79	10	49
Participation level	96.55%	15.38%	75.61%
Activity 3			
Length of activity	13 weeks	6 weeks	7 weeks
Topic of inquiry	Buoyancy and relative density	Physical and chemical reactions involved in making a recipe	Aviation and combined effects of several forces acting on a plane
Participants (number of students; number of adults)	Groups a and b (29;2)	Groups a and b (39;4)	Groups a and b (42;3)
Notes created (adults included)	51	71	50
Participation level	72.40%	42.62%	92.86%
Activity 4			
Length of activity			3 weeks
Topic of inquiry			Chemical and physical reactions involved in making ice cream
Participants (number of students; number of adults)			Groups a and b (42;3)

[13] The participation level refers to the number of students that contributed at least one note to the database out of the total number of students in both classrooms.

Notes created (adults included)	45
Participation level	97.62%

Levels of Participation

As expected, participation levels varied across sites, groups and activities throughout the year. Figure 1 illustrates this variation across sites, collapsed across groups.

This graph shows that the three sites started with a rather high level of participation, which was generally maintained across activities in Sites A and C (higher than 76 %). In Site B, however, the level of participation fell dramatically (from 74.26 % to 15.38 %) for Activity 2 but picked up again for Activity 3 (42.62 %). This low level of participation for Activity 2 was expected since the teachers had jointly decided to do without the Knowledge Forum for this activity, to focus their work in each of their classrooms individually. However, they had noticed that the students were interested in a particular question in both classes, which they ended up posting on the database. Without much incentive to tackle this question online, only 6 students posted some notes during this activity, resulting in this low participation level.

What is more surprising is the participation level for Activity 3 which is rather low considering the teachers' efforts to include the Knowledge Forum in each science period for this activity, as reported in the interviews. Since the students worked in teams for this third activity, and because sole authors often wrote the notes, we may infer that some of the students posting on the database for their teams did not systematically add their co-authors, therefore generating lower participation levels than the reality.

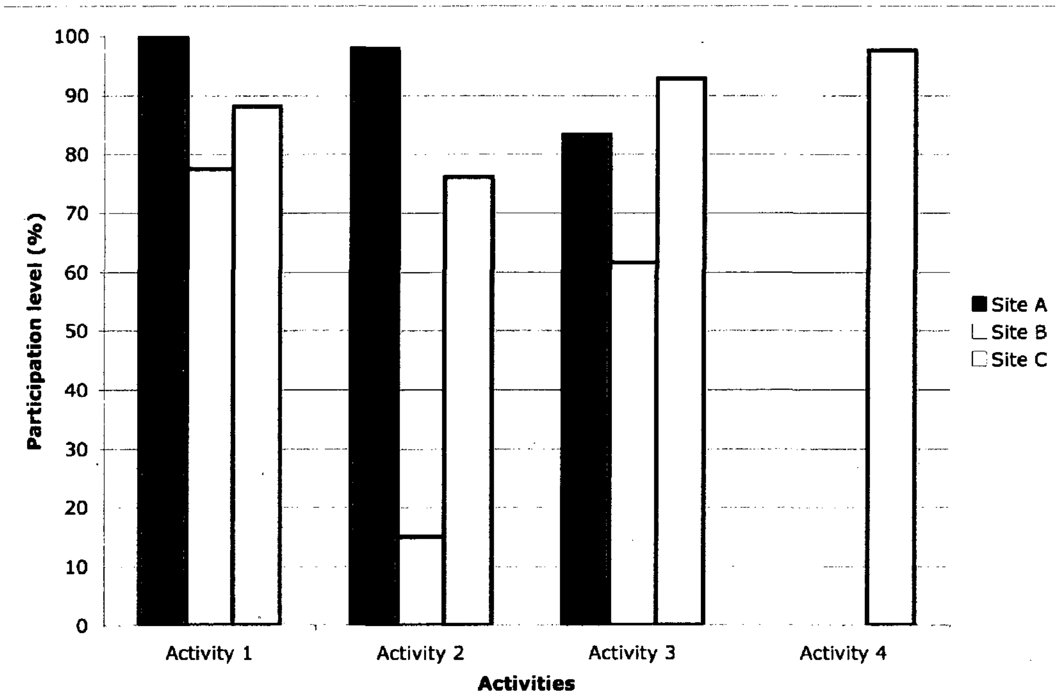

Figure 1. Participation level for each activity per site.

Figure 2 shows the participation levels for each group. This figure shows that each site generally follows the same participation level pattern. In three instances, however, different patterns occur between collaborating groups.

For Site A, Activity 3 shows different levels of participation between the two groups: while A3b maintained its 100% level of participation, A3a dropped from 95.83 % to 66.67%. Recall that A3b has only 5 students, so this 100 % level of participation is much easier for them to achieve than in all the other groups. However, A3a had a relatively high level of participation in the first two activities, which leaves us wondering what happened in Activity 3. In fact, Activity 3 coincides with the arrival of a new teacher, who took over the online activities, but who was in her first year teaching and lacked the first teachers' experience in collaborating with A3b online. The participation level of her group, however, can still be considered high, compared to the groups from the other sites, which unlike Site A, did not experience such an important classroom change during the year.

For Site B, in Activity 3, there is a big difference in participation between B3a (40%) and B3b (83.33%). B3a students neglecting to add their co-authors might explain this, however sole authors from B3b also contributed a lot of notes.

Finally, there is a difference of participation in Site C for Activity 2, where C3a's participation level (57.14 %) was much lower than C3b's (95.24 %). Since both groups worked on this project over a short period of time (3 weeks), and the teachers talked to each other to coordinate the work everyday for the entire duration of this project, such a discrepancy is surprising.

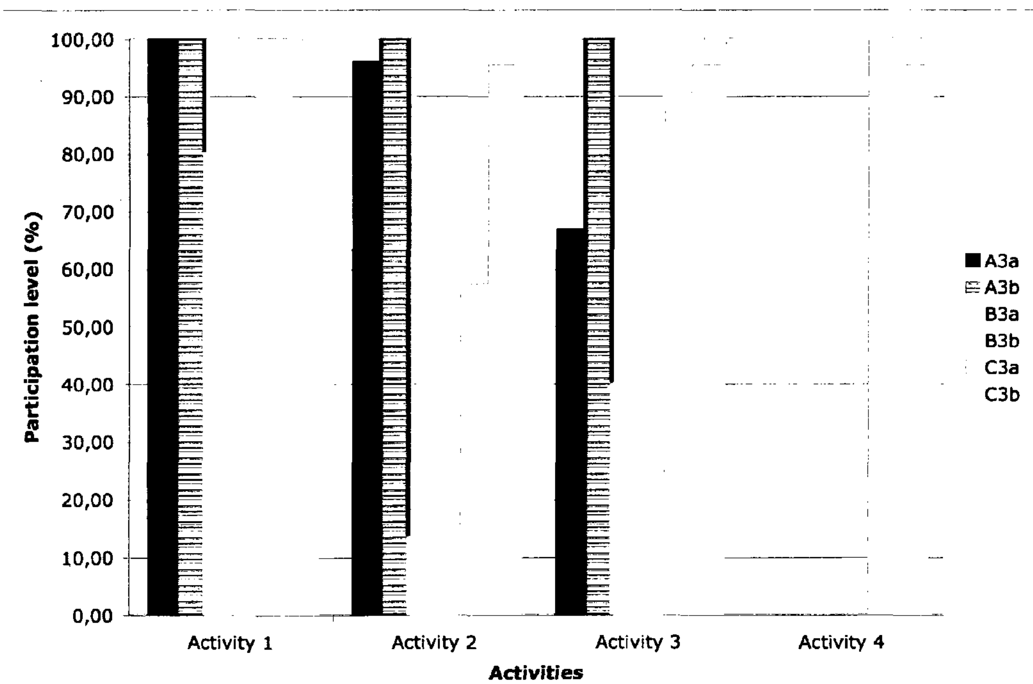

Figure 2. Participation level of students to each activity, per group.

Note Creation

Another way to look at the level of participation at the different sites is to look at the quantity of notes contributed by the different groups during the school year. Figure 3 illustrates the overall contribution of each site to their respective database[14]. Variations across the year are different across sites, as expected. On the one hand, Site A contributed 61, 79 and 51 notes, a somewhat constant number of notes across activities. Site B, on the other hand, when from 81 to 10 to 71 notes, which was explained earlier by a decision not to use Knowledge Forum in Activity 2 as much as in the two other activities. Site C shows the most constancy with the creation of 42, 49, 50 and 45 notes across the year.

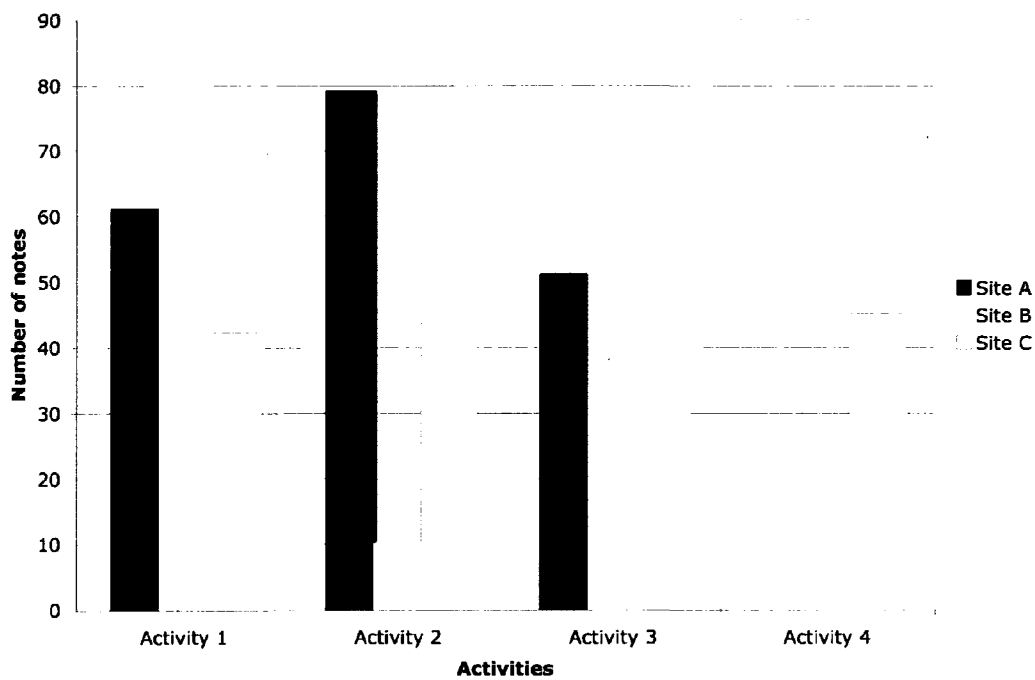

Figure 3. Number of notes created per site (adults included).

[14] The following data refers to the actual notes created i.e., and not the contributions computed by the Analytical Toolkit ([ATK], Burtis, 2001), the main difference being that the ATK computes one note written by two authors twice, and one written by three authors, as three notes.

Individual Participation Data

The previous results gave us an overall understanding of level of participation and the quantity of notes created by each site during the year. This section will present the results of various analyses conducted on individual participation data, more specifically related to each students' individual note creation. First, we will present the means and standard deviations of each site, for each of its activity. In the next section, the results from specific statistical analyses on this data will be presented. The following table (Table 3) presents the means and standard deviations of each site and each activity, adults excluded.

Table 3

Student contributions: Means and Standard Deviations (in parentheses)

	Activity 1	Activity 2	Activity 3	Activity 4
Site A	3.3103 (1.62796)	3.1724 (3.52612)	1.9655 (2.11259)	
Site B	1.8718 (2.40809)	0.2051 (0.52212)	1.5897 (1.5512)	
Site C	1.4524 (1.08656)	2.6667 (2.14893)	1.3571 (0.65598)	3.7857 (0.89812)

The previous table shows three things. First, site A shows a higher mean than both other sites in three activities, the highest mean of all being for site C's Activity 4. Second, that the means are not constant across activities in any of the sites. Third, that site B's peak means are a bit higher than site C's lowest means and that in all three activities, students from site B contributed fewer notes than site A's students. We will see later how significant this difference in contribution is. Figure 4 illustrates each group's mean.

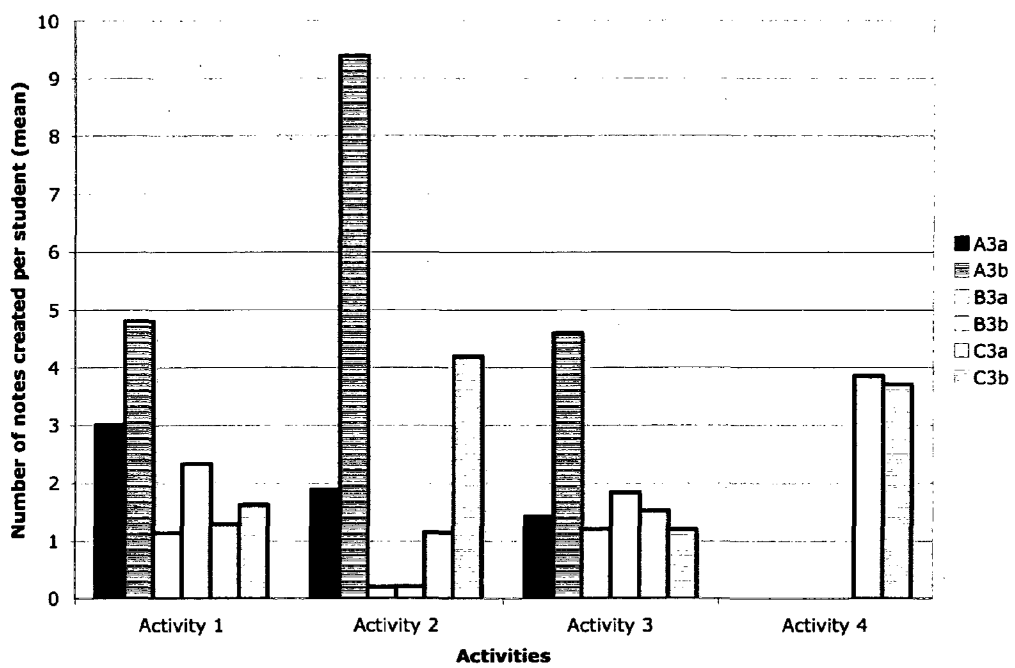

Figure 4. Student contributions per group, across activities.

This figure clearly shows how A3b's participation is different compared to all the other groups. While A3b means range from 4.6 notes/student to 9.4 notes/student, the other groups do not even reach 4.0 notes/student in either activity, except for C3b in Activity 2. The fact that A3b has only 5 students might explain how easier it is for them to access the computers but also their motivation to interact with others. Also noteworthy is their teacher's motivation to work with others and benefit from new ideas. It is therefore not surprising that this group managed to contribute as much as they did to the database. Variations in participation across the other groups, though, are more complex to explain. Some groups such as A3a had a lot of problems with their computers and Internet connection, which may explain to some extent their lower participation rate, as well as the change of teacher midyear, which surely affected classroom ethos.

Both groups in site B had greater access to computers but their teachers lost motivation to participate during the year and so did the students. Site C groups had more students overall but the same number of computers to work with which led to a greater student/computer ratio. They experienced technical difficulties that hindered their efforts but overall they did not experience any particular setback.

Statistical Analyses

Note Creation

Before reaching any conclusions about the use of Knowledge Forum to support student learning, we wanted to compare the different sites between them, in terms of their productivity on the Knowledge Forum. This should help us identify if and how one site is different from the other, first from a purely quantitative manner. In order to identify significant effects, if any, between the groups, a series of statistical analyses[15] were thus conducted.

A first analysis was conducted on the total number of notes contributed to the database for each student. The independent variables for this study were site (A, B, C), group (a, b), grade (5, 6) and gender (g, b) as well as the subjects themselves. The dependent variable was the total number of notes created per student. The design symbolization for this analysis is:

$$\text{Subjects}_{110}(\text{Site}_3 \times \text{Group}_2 \times \text{Grade}_2 \times \text{Gender}_2)$$

Accordingly, an analysis of variance was conducted on the dataset. First, the analysis showed a significant main effect of site ($F(2,87) = 68.351, p < 0.001$). This effect indicates that the total number of notes created was significantly

[15] The use of estimated marginal means for the statistical analyses accounted for the uneven cells.

different in the different sites. Indeed, there was a significant difference between the means of site B (M_B = 3.50, *SD* = 0.50) and the means of two other sites (M_A = 12.41, SD = 0.68 and M_C = 9.09, *SD* = 0.46), which was confirmed by a post hoc analysis using Tukey's HSD. These results confirm a difference in the overall use of Knowledge Forum to support their inquiry process between each site during the year.

Second, the analysis showed a significant main effect of group ($F(1,87)$ = 80.614, $p < 0.001$). This effect indicates that the total number of notes created was also significantly different according to the groups. Group b students (*M* = 10.99, *SD* = 0.49) created significantly more notes than group a students (*M* = 5.56, *SD* = 0.49) collapsed across sites. The overall difference between groups needs to be interpreted further: why are pilot groups less active then their partner group? We shall discuss this effect further later in this chapter.

Third, the analysis showed a significant main effect of grade ($F(1,87)$ = 19.041, $p < 0.001$). This effect indicates that the total number of notes created was also significantly different according to grade. In this case, grade 6 students (*M* = 9.16, *SD* = 0.46) created significantly more notes than grade 5 students (*M* = 7.23, *SD* = 0.43).

Finally, the analysis revealed a significant Site × Group interaction effect ($F(2,87) = 23.235$, $p < 0.001$) which means that the variation between groups was greater in some sites than in others. Figure 5 illustrates this interaction effect. As we can see in the figure, there is a similar difference between groups a and b in sites B and C whereas in site A, the difference between the two groups is much greater. As we mentioned earlier, the 5 students in group A3b contributed individually more than all the other groups of this research project across the year, as their mean number of notes per students quite clearly shows. We might explain such a difference by an easier access to the computers and related small student/computer ratio but another factor that cannot be undermined is the students' eagerness to work collaboratively and their teachers' own motivation to use the tools to enrich their learning experience.

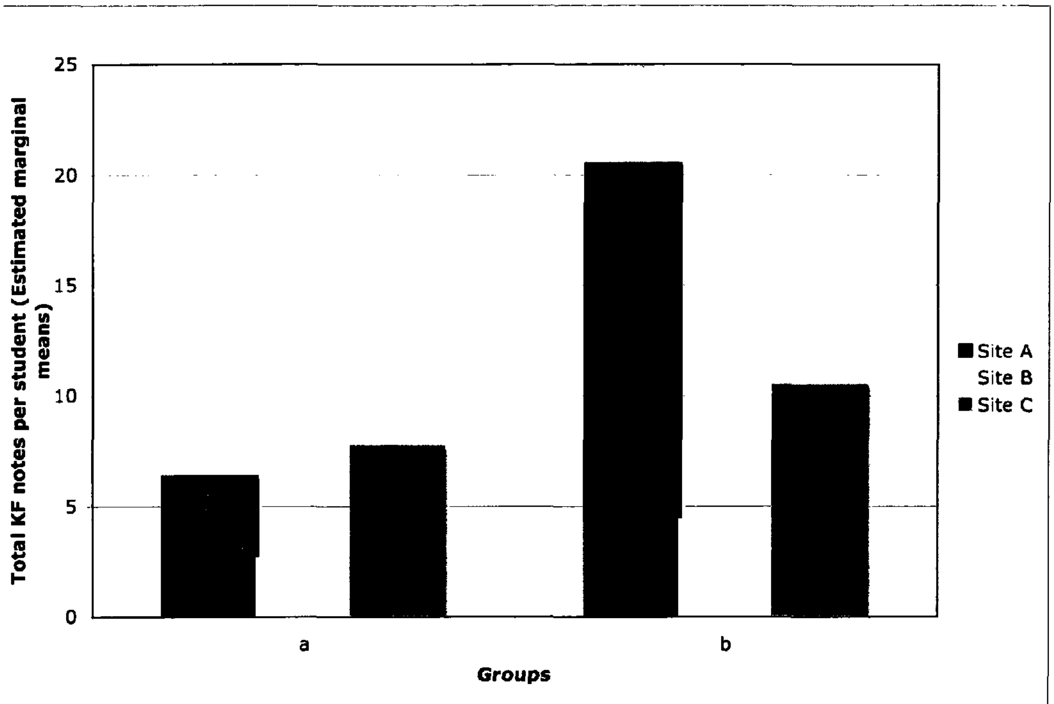

Figure 5. Significant Site × Group interaction effect (All sites, n = 110).

This section looked at the total number of notes created per students in each site collapsed across activities. The following sections will present more closely each sites' note creation results across each activities.

Note Creation – Site A

Three activities were conducted in site A during the year. Each activity generated a number of notes from both collaborating groups. A statistical analysis was needed in order to identify if and how the groups have differed in participation during these activities. The dependent variables for this analysis were the number of notes created per student in Activity 1, 2 and 3 as well as the total number of notes created (Activity 1, Activity 2, Activity 3 and total). The independent variables were group, grade and gender. The design symbolization for this analysis is:

$$Subjects_{29}(Group_2 \times Grade_2 \times Gender_2)$$

Accordingly, in order to analyze the results for this site, a multivariate analysis of variance (MANOVA) was conducted.

First, the analysis showed a significant multivariate effect of group ($F(3,20) = 27.144$, $p < 0.001$). The following Figure 6 illustrates this effect. Univariate tests on each variable show that this effect of group is significant for all of them: Activity 1 ($F(1,22) = 6.409$, $p = 0.019$) Activity 2 ($F(1,22) = 56.314$, $p < 0.001$), Activity 3 ($F(1,22) = 17.390$, $p < 0.001$) and the total ($F(1,22) = 72.427$, $p < 0.001$).

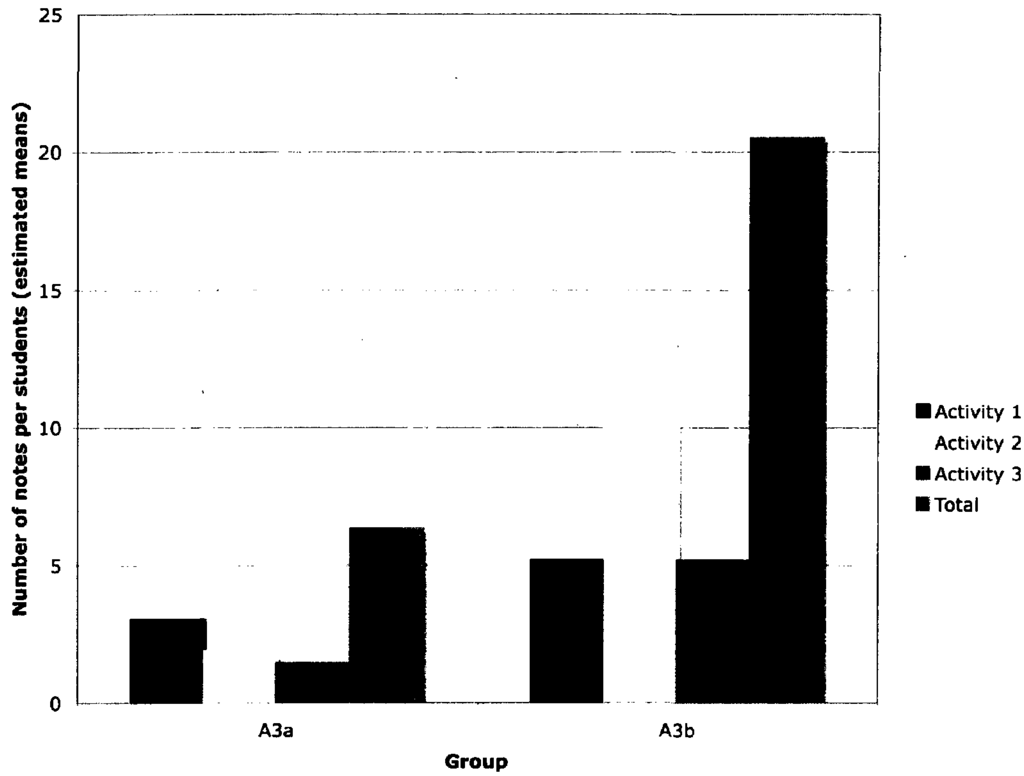

Figure 6. Multivariate effect of group (Site A, n = 29).

This figure clearly shows the difference in note creation between the two groups in Site A. Group A3b's means are always higher than group A3a's means, showing a much higher level of participation to the online collaborative work than group A3a. With such a difference between groups, it is surprising that group A3b maintained its productivity throughout the year. One might think that one small group generating a high number of notes per student could counterbalance a bigger group generating a lower number of notes per student, in terms of overall note creation frequencies, but in this case, we know that group b was often found waiting for their partners to contribute their notes and this lack of reciprocity did hinder the students' as well as the teacher's motivation as the year advanced. In fact, Activity 3 was considered quite negatively by Teacher b during the last interview because of the numerous delays that such lack of coordination between the two groups created.

Second, the MANOVA shows a significant multivariate effect of grade ($F(1,22) = 3.636, p = 0.031$). Figure 7 illustrates this effect. On all the variables, grade 6 students scored higher means than grade 5 students. Furthermore, univariate tests on each variable show that this effect of grade is significant for two of them: Activity 3 ($F(1,22) = 5.413, p = 0.030$) and the total ($F(1,22) = 11.367, p = 0.003$).

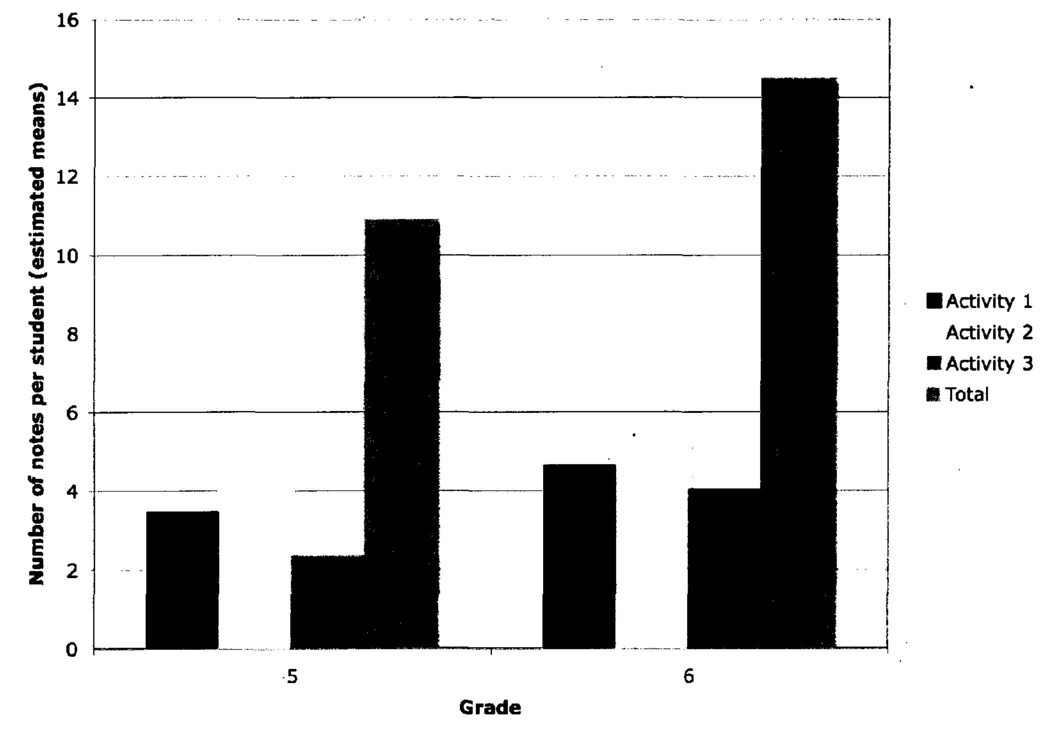

Figure 7. Multivariate effect of grade (Site A, n = 29).

Finally, although there was no multivariate interaction Group × Grade effect, univariate analysis showed a Group × Grade effect on the total number of notes ($F(1,22) = 4.754$, $p = 0.040$). The difference between grade 5 ($M = 16.25$, $SD = 1.50$) and 6 ($M = 29.00$, $SD = 3.00$) students in group A3b was greater than the difference between grade 5 ($M = 5.46$, $SD = 0.94$) and 6 ($M = 7.208$, $SD = 0.90$) students in group A3a.

Note Creation – Site B

Two complete activities were conducted in site B during the year using Knowledge Forum but during a third activity (Activity 2), students were invited to answer one question, so the total number of activities we will examine is three. A statistical analysis was conducted in order to identify if and how the groups might have differed in participation during these activities.

The dependent variables for this analysis were the number of notes created per students in Activity 1, 2 and 3 as well as the total number of notes created (Activity 1, Activity 2, Activity 3 and total). The independent variables were group, grade and gender. This time there were 39 subjects. Again, a multivariate analysis of variance (MANOVA) was conducted.

In this site only, the analysis showed a significant multivariate effect of gender ($F(3,29) = 2.993$, $p = 0.047$).Figure 8 illustrates this effect and clearly shows that while boys contributed more in Activity 1, they contributed less notes than the girls in Activity 3 and overall. Univariate analyses on each variable showed a univariate effect of gender on Activity 3 ($F(1,31) = 5.509$, $p = 0.025$). No other effect was shown.

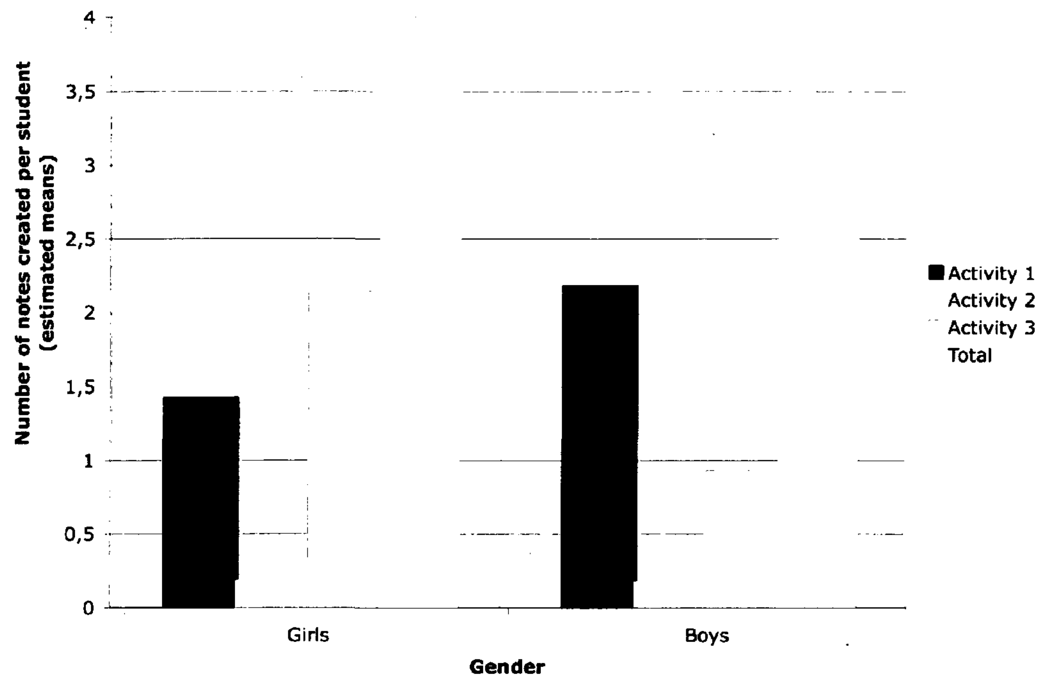

Figure 8. Significant multivariate effect of gender (Site B, n = 39).

With neither multivariate nor univariate effects of group and grade, we can conclude there was no difference of note creation between students from collaborating groups, nor between students from both grades in this Site. This means that individually, the two groups contributed similarly to the collaborative online discussion. However, both groups from site B contributed much less than the other two sites with mean notes contributed totaling less than 5 notes/student for the entire school year. With such a low level of note creation, the possibility of working online having had any convincing impact on student understanding seems rather thin.

Note Creation – Site C

A multivariate analysis of variance was also conducted on note creation data from site C. Dependent variables for this analysis were the number of notes created per student in Activity 1, 2, 3 and 4 as well as the total number of notes created (Activity 1, Activity 2, Activity 3, Activity 4 and total). There were 42 subjects in this analysis.

As for site A, the analysis showed a significant multivariate effect of group ($F(4,31) = 12.060, p < 0.001$) for this dataset. Here too, group C3b means were overall higher than group C3a means as we can see in Figure 9. Furthermore, univariate analyses showed a significant effect of group on two variables: Activity 2 ($F(1,34) = 41.927, p < 0.001$), and Total ($F(1,34) = 13.279, p = 0.001$).

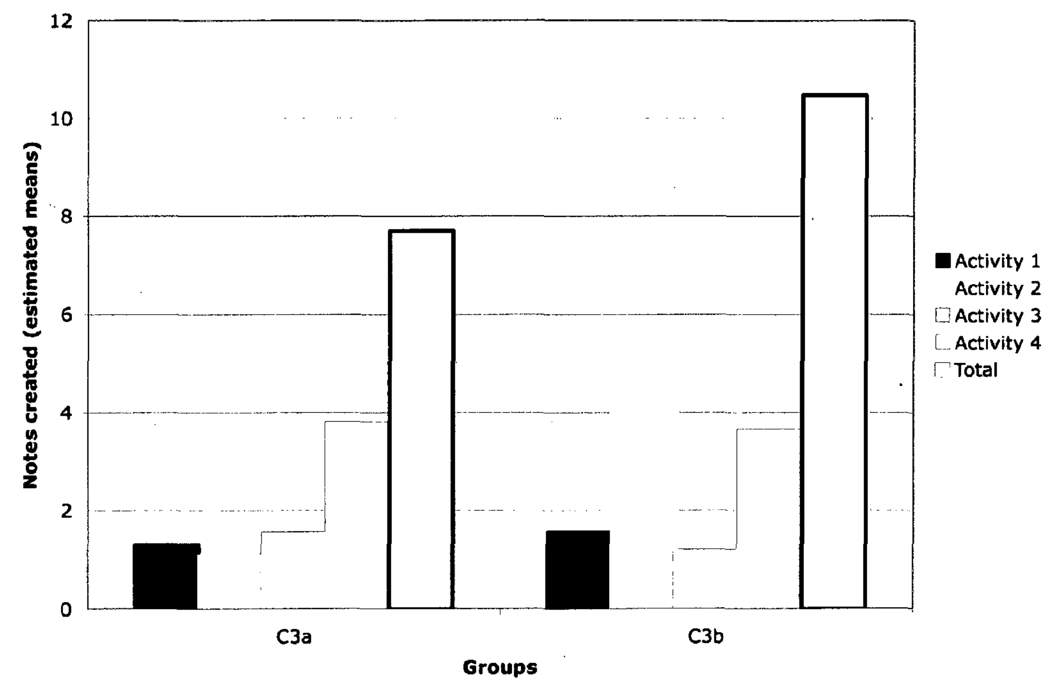

Figure 9. Significant multivariate effect of group (Site C, n = 42).

The above figure shows the apparent difference in note creation more specifically in Activity 2 and in the total number of notes created by the students. In both cases, group C3b created more notes than group C3a, and significantly more so. For example, during Activity 2, students from group C3b created a mean of 4.092 notes/student while group C3a's students created only 1.083 notes/student. Group C3a contributed slightly more notes than group C3b in only one activity, Activity 3, for which both groups created less than 2 notes per student. Activity 1 also generated rather low means but, surprisingly, both teachers considered Activity 3 much more productive. The fact that Activity 1 spread over the whole term may very well explain their appreciation of this first online activity. During the interviews both site C teachers mentioned the duration of the project as a factor of disengagement for students as well as themselves. Teacher A3b mentioned this also. Not surprisingly, it was more engaging for students to work on a specific inquiry topic over a short period of time than have it drag it on for too long.

While there was no multivariate effect of grade, separate ANOVAs show significant effects of grade for the same two dependent variables: Activity 2 ($F(1,34) = 5.354, p = 0.027$) and Total ($F(1,34) = 7.462, p = 0.010$). In both cases, grade 6 students contributed significantly more notes than grade 5 students to the database.

The MANOVA also showed a significant multivariate Gender × Group interaction effect ($F(4,31) = 2.794, p = 0.043$). In each activity, in both groups, girls generated higher means than boys, with the exception of Activity 3 for group C3b and Activity 4 for group C3a. The univariate analyses showed no significant effect.

Use of Scaffold Supports

All Sites

To try to answer our first research question, which is how the use of prompts such as scaffold supports could help students to better understand and put into practice an inquiry process, we first assessed the overall student use of the scaffold supports across activities and across sites. As for the note creation data presented above, there was no initial hypothesis concerning each site's productivity but this comparison aimed to provide a general idea of what to expect when such a study unfolds in six different classrooms. Figure 10 illustrates the means of the scaffolds used, across activities and across sites.

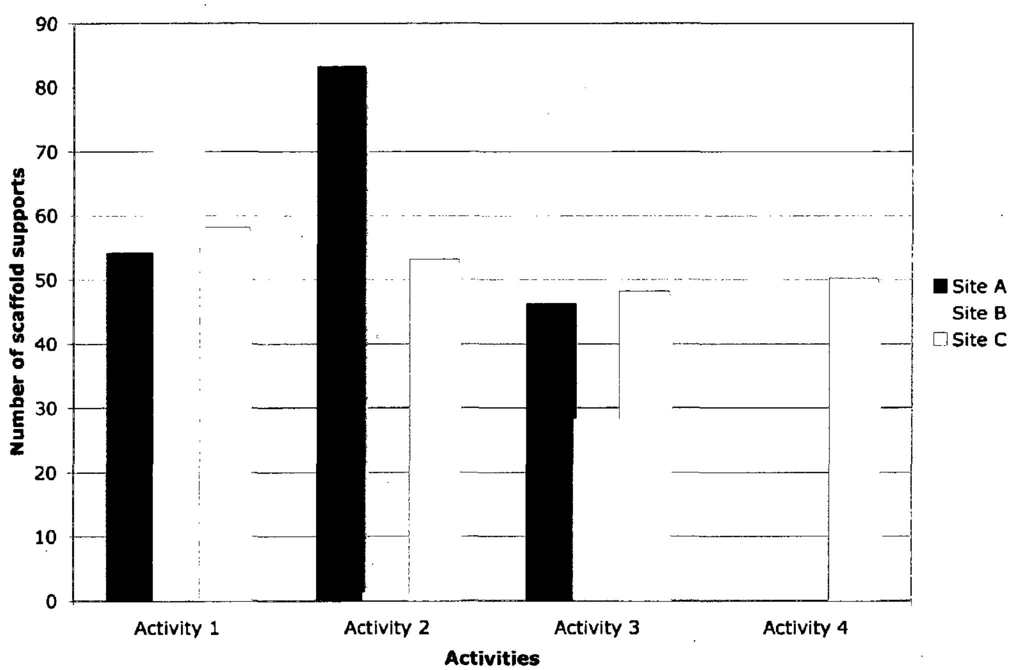

Figure 10. Use of scaffold supports across activities (adults included).

When we compare the number of scaffolds used and the notes written by the students, we can see that there are patterns in the different sites regarding the students' use of scaffolds in their notes. In sites A and C, the use of scaffold supports generally follows the creation of notes, which varies across activities. In site B, although there was a great use of scaffold supports in the first activity, the students used the scaffolds much less systematically in the third activity. A couple of reasons may explain these patterns. Some activities were more or less inquiry-related, thus making it more difficult for the teachers to justify the use of the scaffolds to their students. In other cases, the students themselves found them less appropriate (e.g., in site B's Activity 3). However, we can infer that the student use of scaffold supports was also directly related to the teachers' insistence on using them or not when students worked on their notes. If some chose not to insist on the use of scaffold supports, then a high level of scaffold use from their students was unlikely.

While the overall number of scaffolds used illustrated the students' use of this affordance, it did not inform us about *which* scaffolds were mostly used. The following graphs show which scaffold supports were used at each sites, collapsed across activities (Figure 11, Figure 12, and Figure 13).

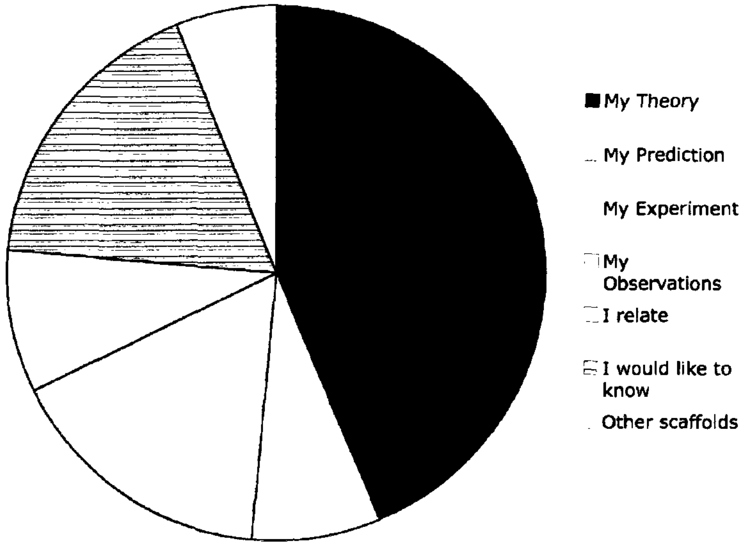

Figure 11. Types of scaffold supports used (Site A).

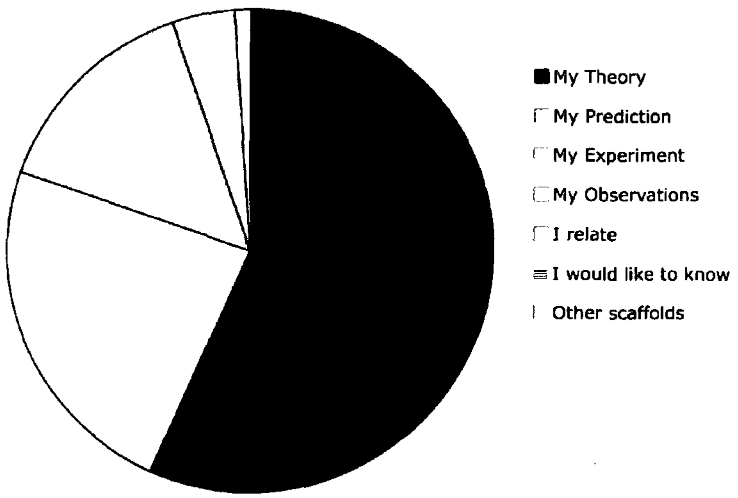

Figure 12. Types of scaffold supports used (Site B).

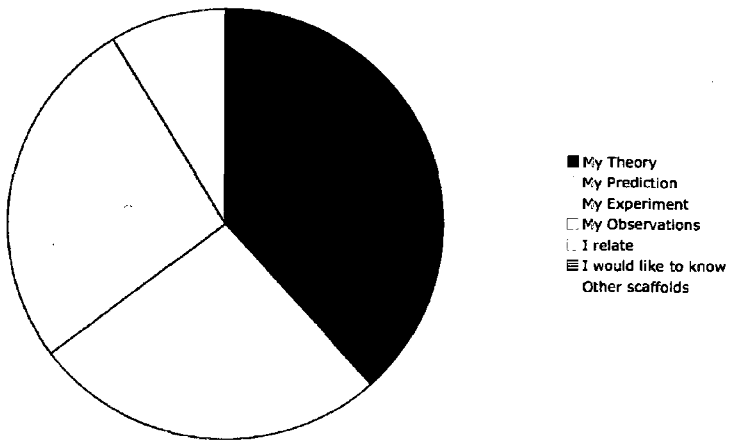

Figure 13. Types of scaffold supports used (Site C).

In all three cases, the type of scaffold support mostly used is *My theory* (38.28% to 56.12%). The second most commonly used scaffold support is *I would like to know* (14.88%) for site A, *My prediction* for Site B (23.47%) and *My observations* for site C (26.79%) with *My prediction* as a close third (26.32%). While the objective was to ultimately get the students to link theories and predictions to what they observed during the experiments and create notes on the database which would explain the observed phenomena, it is not surprising that this scaffold support, *I relate*, was not used nearly as often as *My theory* or *My prediction*, nor that it was even completely ignored in site B. Indeed, the teachers from each site mentioned that they rarely took the time to go back to the initial theories once the "hands-on" experiment was over because the students were less motivated to do so. They also all recognized that the students would have gained a better understanding of the phenomena explored if they did, as they reflected on how taking the time to think about the problem before doing the experiment, for example as they constructed theories and predictions, was enriching for the students. This illustrates the discrepancy between the importance given to the use of inquiry-based scaffold supports in the initial research design and how it translated in the teachers' classroom practice. We shall discuss this further later.

Now if we look at the scaffold used across activities for each site, we can see some tendencies emerging with time. In site A, the use of scaffolds varies across activities, with a tendency to use *My theory* the most often. However, there is a steady increase in the use of *I would like to know*, which indicate a greater number of questions asked in this database across activities. In site B, although a variety of scaffold supports were used in the first activity, they seemed to have been largely dropped in favor of using only *My theory* in the third activity. The second activity, with its only one scaffold used out of 10 notes hardly counts. Site C shows a gradual increase in the use of *My prediction* scaffold supports with time which was the most often used scaffold support in Activity 4.

Statistical Analyses of Scaffold Support Use

All sites

The previous results gave us an overall understanding of the level of use of the scaffold supports by the students across different activities. This section will present the results of various analyses conducted on individual student data collected related to each students' use of those scaffold supports.

To this end, a first analysis was conducted on the total number of scaffolds per student used at each site. The independent variables for this study were site (A, B, C), group (a, b), grade (5, 6) and gender (g, b) as well as the subjects themselves. The dependent variable was the total number of scaffold supports used per student. The design symbolization for this analysis was:

$Subjects_{110}(Site_3 \times Group_2 \times Grade_2 \times Gender_2)$

An ANOVA was conducted on the dataset and it showed a significant effect of site ($F(2,87) = 101.871, p < 0.001$). This indicates a significant difference in the use of scaffolds in the different sites, as expected from the means ($M_A = 11.843$, $SD = 0.65$; $M_B = 3.050$, $SD = 0.477$, and $M_C = 11.392$, $SD = 0.438$).

This is consistent with the significant effect of site on the number of notes created per student. These results confirm a difference in the overall use of the Knowledge Forum and its scaffolds to support students' inquiry process between each site during the year. As stated earlier, a hypothesis toward this effect or the contrary was not formed at the outset; the difference between the sites only serves an illustrative purpose.

Second, the ANOVA showed a significant effect of group ($F(1,87) = 50.767, p < 0.001$). Indeed, students in group b collapsed across sites, used more scaffolds ($M_b = 10.845$, $SD = 0.469$) than the students in group a ($M_a = 6.595$, $SD = 0.383$). This effect was similar for the notes created.

Third, the ANOVA showed a significant effect of grade ($F(1,87) = 14.252$, $p < 0.001$). Grade 6 students ($M_6 = 9.499$, $SD = 0.439$) used more scaffold supports than grade 5 students ($M_5 = 7.828$, $SD = 0.412$). The same effect was observed on the note creation data.

Finally, the ANOVA showed a significant Site × Group interaction effect ($F(2,87) = 29.403, p < 0.001$) i.e., that the difference in scaffold use between students from collaborating groups was more or less important depending on the sites. As we can see from Figure 14, in site A, group b students used far more scaffold supports than group a students. In site C, this difference was less important. In site B, students in group a used scaffolds slightly more than students in group b. Again the same differences were noted in the note creation data.

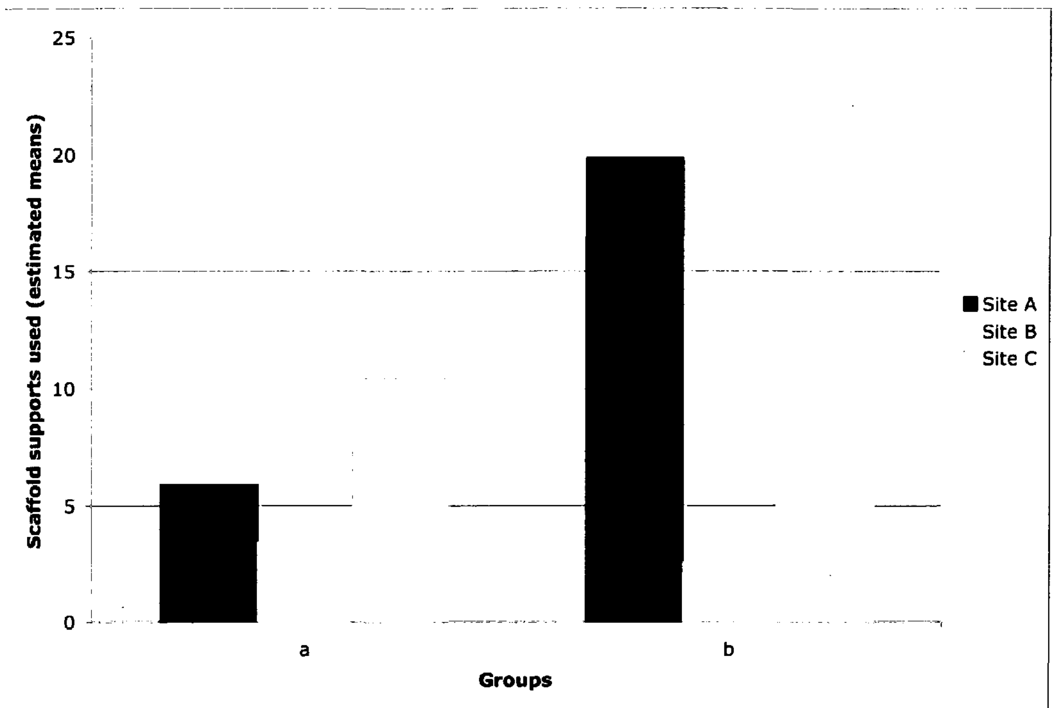

Figure 14. Significant Site × Group interaction effect for the use of scaffold supports.

This section looked at the scaffold used in each site collapsed across activities. The following sections will detail each site's scaffold use across activities.

Scaffold Support Use – Site A

A statistical analysis was conducted to identify if and how the groups might have differed in their use of scaffold supports during the three science activities carried out in site A during the year.

The dependent variables for this analysis were the number of scaffolds used per students in Activity 1, 2 and 3 as well as the total number of scaffolds used (Activity 1, Activity 2, Activity 3 and total). The independent variables were group, grade and gender. The design symbolization for this analysis is:

$$\text{Subjects}_{29}(\text{Groups}_2 \times \text{Grade}_2 \times \text{Gender}_2)$$

A MANOVA first revealed a significant multivariate effect of group ($F(3,20) = 29.340, p < 0.001$). Univariate analyses of group on each dependent variable also showed significant effects for Activity 2 ($F(1,22) = 89.963, p < 0.001$), Activity 3 ($F(1,22) = 23.459, p < 0.001$), and Total ($F(1,22) = 65.609, p < 0.001$). Figure 15 illustrates the multivariate effect. We can see from this figure that overall, group A3b students used much more scaffolds than group A3a students, except in Activity 1. This difference was most obvious in Activity 2.

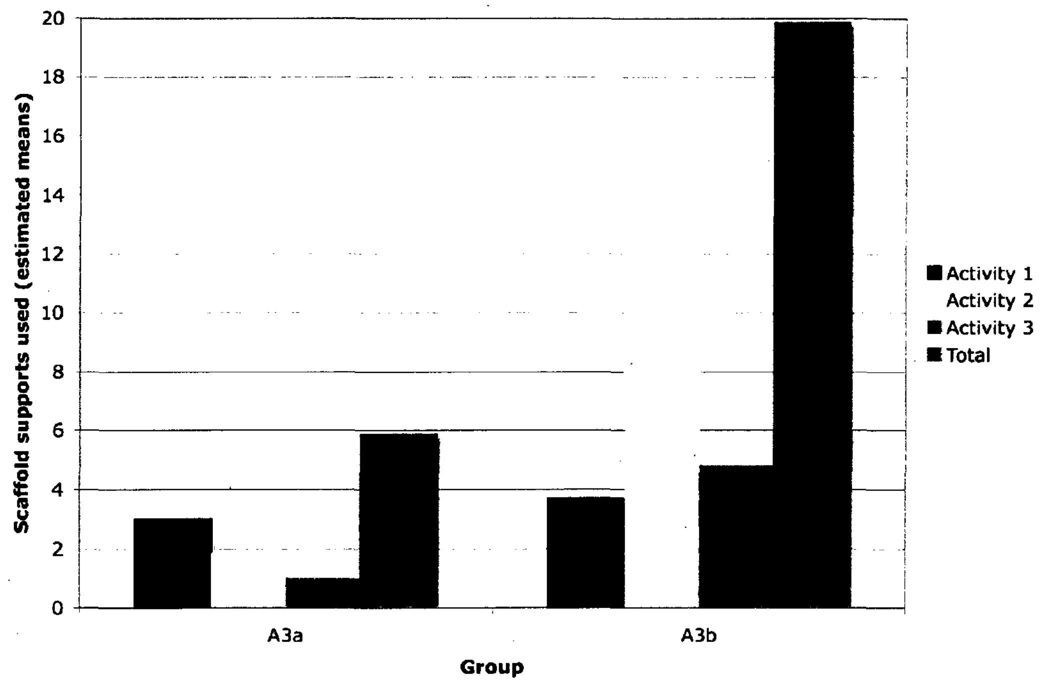

Figure 15. Multivariate effect of group (Site A – scaffold support use).

No other effect was significant for site A i.e., contrary to the note creation data, there was no significant effect of grade on scaffold support use nor any significant Group × Grade interaction effect. This means that although grade 6 students wrote more notes than grade 5 students, they did not use more scaffold supports than their younger peers.

Scaffold Support Use – Site B

Three activities were also conducted in site B during the year. The second activity however consisted of only one question, but we shall consider it nonetheless. Here too, a statistical analysis was needed in order to identify if and how the groups might have differed in their use of scaffold supports during these activities.

The dependent variables for this analysis were also Activity 1, Activity 2, Activity 3 and total and the independent variables were group, grade and gender. There were 39 subjects in this analysis. The MANOVA revealed no significant multivariate effects, unlike the analysis on note creation that revealed a significant effect of gender. However, separate univariate analyses showed a significant effect of grade on two variables, Activity 1 ($F(1,31) = 4.896, p = 0.034$), and total ($F(1,31) = 26.629, p = 0.032$). In both cases, grade 6 students used more scaffolds than grade 5 students.

Again, in general, site B students created many fewer notes and they used far less scaffold supports than both other sites. However, there was not a significant distinction in their productivity or use of these affordances between the two classrooms which leads us to believe that both teachers put much less emphasis on their students' online collaborative work and the use of scaffolds than their colleagues from the other sites. This is further confirmed by notes from discussions throughout the year between the researcher and site B teachers as well as discussions with their pedagogical consultants.

Scaffold Support Use – Site C

Four complete activities were conducted in site C during the year. The same analysis was conducted. The dependent variables were Activity 1, Activity 2, Activity 3, Activity 4 and Total and the independent variables were group, grade and gender. There were 42 subjects.

As it was the case for the note creation data, the MANOVA revealed a multivariate effect of group ($F(4,31) = 26.449, p < 0.001$). Univariate tests also showed significant effects of group on Activity 1 ($F(1,34) = 21.824, p < 0.001$) and Activity 2 ($F(1,34) = 58.331, p < 0.001$). As we can see from the Figure 16, there is no clear tendency in the use of scaffolds between groups; in Activity 1, group C3a uses more scaffolds, whereas in Activity 2, group C3b uses more scaffolds.

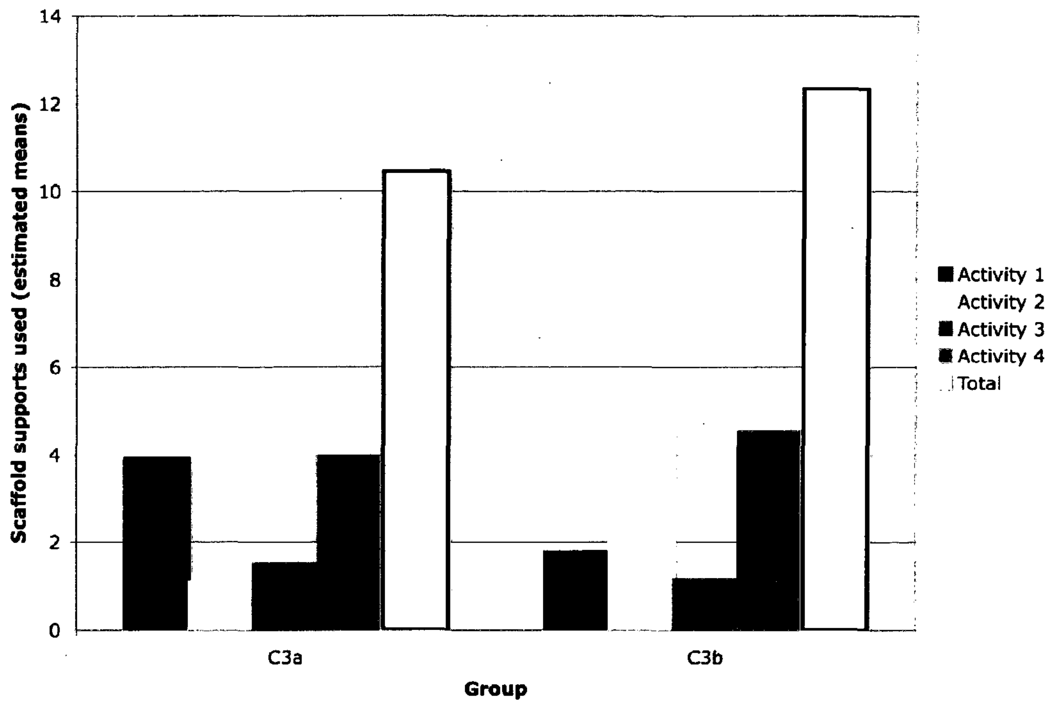

Figure 16. Multivariate effect of group (Site C – scaffold support use).

Univariate analyses also showed significant effects of grade on Activity 2 (F(1,34) = 6.369, p = 0.016) and Total (F(1,34) = 6.949, p = 0.013). On these two variables, grade 6 students used more scaffolds than grade 5 students. Similar univariate effects were identified on two variables for site A.

Finally, univariate analyses showed a significant Gender × Group interaction effect on Activity 4 (F(1,34) = 5.117, p = 0.030). Girls in group C3b used more scaffold supports than girls in group C3ba, while boys in group C3a used more scaffolds than boys in group C3b.

Coherent Use of Scaffold Supports

Knowing which scaffolds students used and how often they did so in each group does not say whether they were used coherently or not. To this end, I conducted a first content analysis of the notes to assess whether or not the scaffold supports used were used coherently or not, i.e., whether when a students used a *My theory* scaffold, it was indeed a theory that was contributed to the database. For one activity, both the researcher and a second coder coded each scaffold use as coherent or incoherent. The inter-rater agreement for this analysis was 84.78%.

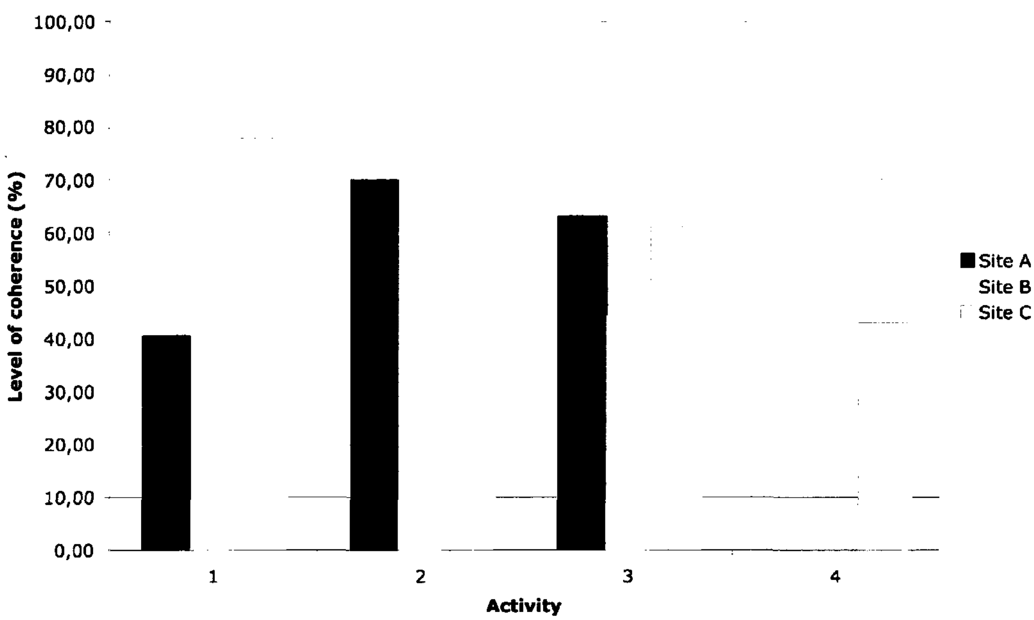

Figure 17. Level of coherence in scaffold use across sites and activities.

Figure 17 shows that while site A has been able to increase its coherence rate both sites B and C have not. Of course, they both started quite high (88.24% and 77.59%, respectively), which leaves less room for an increase than if they started lower, like site A (44.83%). However, this alone cannot explain why they dropped so much over time.

One hypothesis might be the lack of teacher modeling of the coherent use of scaffold supports. Indeed, the teachers themselves did not bother insisting on their use, coherent or incoherent, as they reported in their interviews. It could also be the result of a certain level of uncertainty regarding the scaffolds themselves. At different occasions, the teachers admitted it was difficult for them to distinguish the scaffolds and use them to support their students' inquiry process.

In order to help them deepen their own understanding of the scaffold supports, a view was specially created for the teachers so that they could share their reflections following a first iteration of results before Christmas Break. Unsurprisingly, the results of their students' work illustrated the need to devote more attention to the coherent use of scaffold supports. To this end, the researcher created this online space to collaboratively discuss them with the teachers. All of the teachers were very interested to engage in this discussion at first. However, none but one actually came online to this end, leaving this question unanswered. We believe that this question took a backseat to the teachers' practical considerations such as improving their collaborative process and resolving any remaining technical issues.

The consequence of this probable lack of insistence on the coherent use of scaffolds supports, from our point of view, explains the drop in coherence levels over time. Figure 18 shows the levels of coherence of each group.

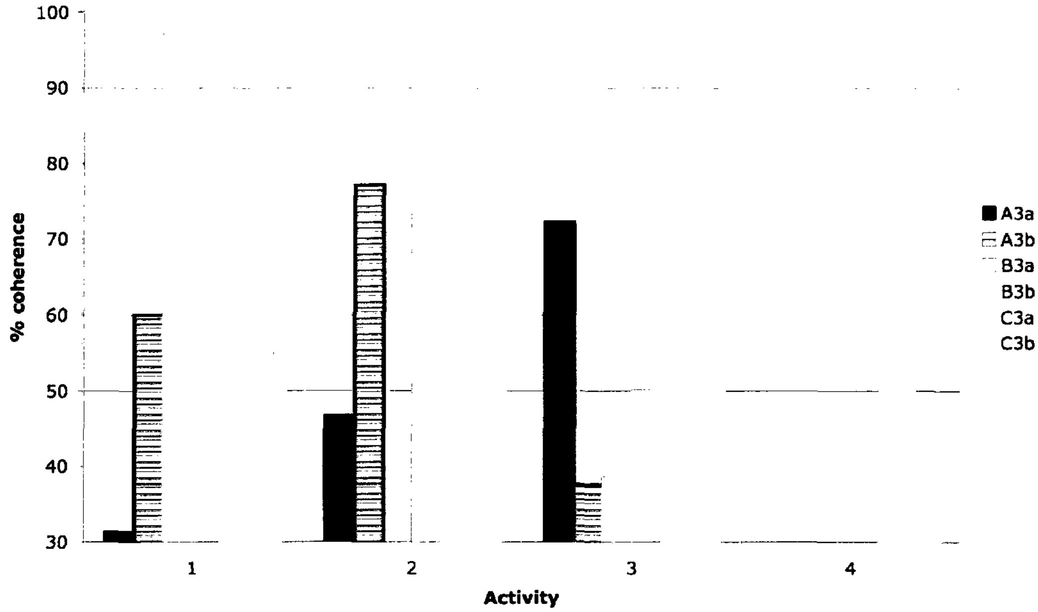

Figure 18. Levels of coherence across activities for each group.

Group A3a shows a continuous and gradual increase from 31.25% to 72.22%. Interestingly enough, their teacher was the only one who actually participated in the online discussion on the scaffold supports. A first-year teacher who seems to have kept up the modeling of the inquiry process later replaced her as she left on maternity leave. Group A3b increased its coherence rate from Activity 1 to 2 but it dropped for Activity 3. Teacher A3b expressed in the final interview a high level of disappointment for Activity 3 that had major impact on his own and his students' engagement. From his point of view, there were important difficulties in getting the students from both groups to collaborate and because of this, the activity dragged on over as much as 13 weeks. This may very well explain a genuine lack of interest for the task that was reflected on the coherence level.

Both groups of site B, excluding the unique scaffold used in Activity 2, show a drop in the coherence rate (from 80% and up to 50% and less). Group C3a remained steady with a 60% coherence in the first 3 activities, while C3b hit a high of 84.85 % for Activity 2 but decreased gradually from there on. Knowing how little the Knowledge Forum was used in these two groups, these results are not surprising. Also recall that during the first activity, the pedagogical consultant created a couple of notes with coherently used scaffolds. Almost all of the students' notes were exactly modeled on hers, which may explains the high coherence level for Activity 1, and further suggest the effect of modeling on student coherent use of scaffolds.

Judging from these results, and keeping our initial hypothesis in mind, we expect the students from site A to have gained a better understanding of the inquiry process than the students from sites B and C. Students from site B do not seem to have used the scaffold very much to support their inquiry process and when they did, they showed an important decrease in its coherent use across activities. The results from the pre- and post-tests on the inquiry cycle should confirm or reject this hypothesis.

Statistical Analysis of Coherence Level

An ANOVA was conducted on the dataset to identify, if and how, the groups differed in their coherent use of the scaffolds. The dependent variable was the total level of coherence across activities (%coherence). The independent variables were once again the following: site, gender, group and grade. There were 101 subjects in this analysis (9 subjects were removed from the dataset because they did not have a coherence score, having not once used a scaffold support, 8 of them from site B). The design symbolization for this analysis is:

$$\text{Subjects}_{101}\ (\text{Site}_2 \times \text{Group}_2 \times \text{Grade}_2 \times \text{Gender}_2)$$

The analysis revealed a significant effect of site ($F(2,78) = 3.748$, $p = 0.028$). Site A's coherence level ($M_A = 52.191$, $SD = 4.443$) was significantly lower than site C's ($M_C = 63.317$, $SD = 3.054$) and site B's ($M_B = 70.291$, $SD = 3.629$).

At first glance, these results are surprising. Indeed, the site with the highest mean, site B, is the site that had used the scaffolds the less. Moreover, when they did use the scaffolds, site B student mostly repeated the same pattern of use as modeled by a pedagogical consultant in Activity 1, as stated earlier. What is also noteworthy is the fact that almost all of the students who did not use any scaffold at all were from site B which could have influenced the mean if, for example, we infer that high achievers would be more comfortable in using the scaffolds, and would use them more coherently than the lower achievers. How could we explain the fact that the more you use the scaffolds, the more likely you are to use them incoherently?

Since almost all of the teachers admitted not having put much emphasis on the coherent use of the scaffolds, it is safe to assume that a coherent use of scaffolds was not seriously modeled by most of them throughout the year, although the researcher and at least one teacher modeled it online. Furthermore, in Site B, it was very clearly modeled in the first activity during which the students used the scaffolds quite often. In the other two activities however, it was not modeled and the use of the scaffolds dropped significantly. In the other two sites, the students maintained the use of scaffolds across activities, but there was hardly any modeling of their use in the database itself by the teachers and hardly any in class as we learned in the interviews. As such, the students used the scaffolds spontaneously but with little to no modeling of their coherent or less coherent use online and presumably in class.

Finally, the analysis revealed a significant Site × Group interaction effect ($F(2,78) = 3.741, p = 0.028$). Indeed, group A3a was less coherent than group A3b, group B3a was more coherent than group B3b and in site C, both groups were as coherent in their use of the scaffold supports.

Pre- and Post-Test Results on the Inquiry Process

This section will look at the results for the inquiry test, which was given to students at the beginning of the school year (pre-test) and again, at the very end (post-test). This test aimed at assessing the students' level of understanding of each step of the inquiry process and how each relates to the other[16].

Ninety-seven students completed both tests: 23 from site A, 36 from site B and 38 from site C. There were 48 girls and 49 boys. There were 51 students from group a classrooms and 46 students from group b classrooms. Forty-six students were in grade 5 and 51 students were in grade 6.The test consisted of 6 questions each rated according to a 3-point scale rubric[17] for a maximum score of 18. The interrater agreement was 83% for this analysis. The independent variables for this analysis were site (A, B, C), gender (g, b), group (a, b), grade (5, 6) and test (pre,

[16] See Appendix C for the test.
[17] See Appendix D for the rubric.

post). The dependent variable was the test score, which had a maximum value of 18. The design symbolization for this analysis is:

$$\text{Subjects}_{97}\ (\text{Site}_3 \times \text{Gender}_2 \times \text{Group}_2 \times \text{Grade}_2) \times \text{Test}_2$$

A repeated measures ANOVA was conducted on the dataset. The analysis first showed a significant within-subjects effect of test ($F(1, 74) = 33.004, p < 0.001$). When collapsed across all other factors, the results of the post-test ($M = 11.661, SD = 0.320$) were significantly higher than the results of the pre test ($M = 9.536, SD = 0.320$).

Although there is an increase in the results of the test, the means are still rather low. Indeed, the maximum score being 18, the relative value of these two means are a little over 50% (pre = 52.96% and post = 64.72%). The questions were said to be too difficult both by the students and by their teachers, in all groups. What is more, during the interview with the teachers at the end of the year, almost all of them said that they should have insisted more on the inquiry process. The added pressure of answering a "researcher's test" may have overly stressed some students.

Although there were differences in term of participation between the three sites (number of notes per students, number of scaffolds, participation levels, etc.), note that there was no significant effect of site on the pre- and post-test scores. In fact, the scores on the pre-test ($M_A = 9.420, SD = 0.647, M_B = 9.964, SD = 0.486, M_C = 9.208, SD = 0.456$) and post-test ($M_A = 11.833, SD = 0.681, M_B = 11.804, SD = 0.511$), $M_C = 11.369, SD = 0.479$) were surprisingly similar.

However, a significant between-subjects Site × Group interaction effect ($F(2, 74) = 5.813, p = 0.005$) was found. This interaction effect indicates that the results collapsed across tests vary significantly between groups depending on the sites. For instance, as shown in the following figure, group A3b (*M* = 13.167, *SD* = 0.553) scored much higher than group A3a (*M* = 8.721, *SD* = 0.553). Since we know that group A3b created far more notes and used far more scaffolds than group A3a, this would seem to confirm our hypothesis.

In site B, both groups have similar results (M_a = 10.500, *SD* = 0.674, M_b = 11.269, *SD* = 0.466), which fit with their similar degree of participation in terms of notes, and scaffold use. In site C, the results are also surprising since group C3b (*M* = 9.556, *SD* = 0.502) created more notes and used more scaffolds but scored lower than group C3a (*M* = 11.021, *SD* = 0.502). What is surprising is the fact that so little participation and consequent use of the scaffolds in site B could lead to a similar effect of test than what the two other more participating sites generated. In other words, why did site B students score as high as site A and C students on the post-test if they hardly used the scaffold supports during the year?

If we look at the coherence results though, group C3a maintained its coherence level across activities, while group C3b's coherence level dropped a little over time. In site B, both groups scored similar results. But could this explain the difference in post-test scores between these two groups? Probably not.

Analysis of Regression

Finally, a stepwise regression analysis on the entire dataset was conducted. The dependent variable for this analysis was the post-test score and the variables examined were the total number of notes, the total number of scaffold supports, the coherence level and the pre-test score for every student regardless of grade, group, gender or site. In order to identify the regression model, the correlation matrix revealed a correlation of the post-test score with the pre-test score of 0.538, with the coherence level of 0.249, with the total number of notes ($p = 0.246$) and the total number of scaffolds ($p = 0.245$). This analysis also confirmed a very high correlation between total notes and total scaffolds ($p = 0.920$). The one-variable model with pre test score as variable was significant ($F = 36.717, p < 0.000$) at $\alpha = 0.05$ and the second-variable model (pre test score, coherence level) was also significant ($F = 21.113, p = 0.043$). The one-variable model generated a coefficient of $\beta = 0.550$ while the two-variable mode generated a coefficient of $\beta = 0.02451$. Both models were thus judged hardly convincing.

The analysis of regression indicates that pre-test scores are the best (but still poor) predictors of post-test scores on the inquiry test and that, at best, the coherence level could also predict to some (very limited) extent the post-test scores. None of the other variables could be used as effective predictors.

Discussion of the Results

Participation Across Sites

In order to analyze the participation of the different sites, we first looked at the levels of participation in terms of the mean number of students who created at least one note per activity out of the total number of students in the class. The results showed that the participation levels varied across activities in each site. When collapsed across groups, sites A and C maintained a participation level higher than 72% while site B peaked at 74.26% and was as low as 15.38% for Activity 2. Judging from these levels of participation and knowing that the teachers did not intend to use the Knowledge Forum for Activity 2, we could in fact consider that Site B students collaborated during two activities, not three.

When we looked at each group separately, we saw that the levels of participation varied between collaborating groups also. For example, while group A3b maintained a 100% level of participation across activities, group a dropped from 100% for Activity 1 to 66.67% for Activity 3. Since group b had only 5 students it was much easier for this group to maintain such a high level of participation. Results also show differences in the levels of participations between groups of the two other sites, the most important difference being for site C's Activity 2, when only 57.14% of group C3a's students participated compared to 95.24% of group C3b's students.

These differences in participation levels may be interpreted in a number of ways. They may reflect differences in the level of interest and engagement of students concerning the online task. They may also reflect differences in the explicit expectations of the teachers regarding their students' participation in the online discussion. They could also indicate some issues regarding the students' access to the computers or simply their personal preferences. What it clearly shows however is that only half of the groups were able to attain a 100% participation level in at least one activity, that is, the entire class writing at least one note in one activity.

Note Creation (Adults Included)

The overall number of notes created for each activity during the year was a second indication of student participation across sites and groups. Site A (n = 29) contributed 61, 79 and 51 notes to the database. Site B (n = 39) on the other hand, went from 81 to 10 to 71 notes. Site C (n = 42) shows the most constancy with 42, 49, 50 and 45 notes across activities. These results tend to confirm a marked difference in participation between sites but more importantly between collaborating groups. The difference in participation between groups has been mentioned in teacher interviews as having greatly impacted student engagement to the task, for example when delays stretched for too long and when the other group's responses were too scarce.

Statistical Analyses – Note Creation

As stated previously, statistical analyses of the total number of notes created across activities and sites showed no effect of gender. A significant effect of site was however observed indicating a difference of participation between the three sites. Overall, site A's mean (12.41 notes/student) was higher than site C's (9.09 notes/student) which were both much higher than site B's (3.50 notes/student).

A significant effect of group was also observed, which confirmed the previous observations. Collapsed across sites, even when groups b (i.e., partner schools) had many fewer students than groups a (i.e., pilot schools), Groups b created significantly more notes (10.99 notes/student) than their collaborating group (5.56 notes/student). This had been confirmed by students' and teachers' comments throughout the year. The result being that when one group is much more present in the discussion than the other, it tends to create an imbalance that hinders the collaborating process: students from one group are often waiting for their partners' notes and can be disappointed when it takes too long or when there are too few notes to work from. Riel and Levin (1990) called this participant structure *Response obligations* and discussed its impact on student motivation.

Now what calls for reflection is the fact that the imbalance was in all cases on the side of pilot schools. Why are pilot schools, who have been identified by their school board as the more in need of RNS-related innovation and tools, not as active as their partners? Is it because they are too much solicited in the RNS project and as a result, have fewer resources to contribute to each activity or project? Is it an effect of their generally lower achievement rates (i.e., that their pilot school students are overall lower achievers and could have more difficulty to collaborative online in written form)? Is it because pilot school teachers are generally more solicited for other school activities since the school staff is often very limited in pilot schools (i.e., small schools share often school principals. This means that at least once a week, no principal is on site. The same can be said for administrative staff, technical staff, etc. Meanwhile, immediate demands still come up and are taken up by the teachers, generating additional work for them)? All of these factors may have played a role in the observed sites.

A significant effect of grade was also observed. Overall, grade 6 students (9.16 notes/student) wrote significantly more notes than grade 5 students (7.23 notes/student), across sites and groups. This could indicate different things. Maybe grade 6 students had more autonomous time to choose what to work on and chose to work at the computers. Maybe grade 6 students were expected to contribute more by their teachers, and their teachers may have made explicit demands to that effect they did not make to grade 5 students. Perhaps grade 6 students were more comfortable with the computers and were more likely to created new notes and contribute to the discussion. Another explanation may be that younger students were less comfortable with writing their ideas and preferred to contribute to an older classmates' note rather than create a note themselves. In such cases, co-authorship may not have been consistently assigned. We might also infer that more occasions were given to the older students to contribute to the database, either because they had more access to the computer (e.g., if it took them less time to complete other assignments and they could go to the computers in their free time).

A significant Site × Group interaction effect was also observed. While in site B and C group b means were a little higher than group a means, in site A the difference was very important. Again, this difference in participation to the online discussion was manifest throughout the year as both group A3b teacher and students were often put in a position were they had to wait for group A3a to send in their notes and reflections, which often hindered their own process. In spite of this, group A3b maintained its engagement across activities although their motivation definitely faltered in the last activity.

Various causes may explain the observed effects. The difference in participation between sites is, as expected, first and foremost the result of teacher pedagogical choices and group realities. For example, Teacher A3b was ready to start the very first week of September. This resulted in a first inquiry activity, conducted in this group only, that generated as much as 50 notes and was a frank success, by the number of notes but also by other standards, such as coherence in the use of scaffolds and understanding of the concepts explored. Other teachers needed a few weeks to establish classroom climate and routines before going ahead with an online collaborative activity. Other teachers had trouble starting their activities sooner because their school was ill equipped. Others still did not have time to meet with the researcher until much later in the Fall and chose not to start anything before they met. While a late start may provide some explanation of the difference between sites, other reasons exist.

As shared by both teachers and their pedagogical consultant, site B, for one, had trouble understanding how to integrate the tool to their inquiry activities. The first activity did not satisfy them although the researcher judged it to be quite interesting. They felt they had failed and had lost interest in the inquiry and that their students in turn had lost all motivation to participate. The inquiry was stopped mid-way. What is more, both teachers had recently received training on specific science toolkits based on active inquiry (using ready-made didactic toolkits) and were interested in using Knowledge Forum to support their student learning but had difficulties planning how one could support the other. Although support to that effect was given by their pedagogical consultant as well as by the researcher, it still took them some time to fully understand how they could use the tool to support the inquiry process. This had for effect that they both specifically chose not to use the Knowledge Forum during the second science activity (except for one question, which led to the creation of only 10 notes), but instead focused on using the toolkit in each of their classrooms. A couple of months later, they felt more comfortable with the toolkits and were ready to try a third and last scientific inquiry, with Knowledge Forum to support their work.

In site C, the first activity was also a semi-success for both groups. The inquiry activity was carried on for far too long (17 weeks, including Christmas Break), teachers and students eventually lost interest in it, and it was also dropped halfway. Then, a couple of weeks went by without any collaboration between the groups because one of the teachers was on leave. But when she returned, both teachers decided to give it a second try and carried out three smaller scientific inquiries almost back to back. They realized that they had better results and higher student engagement when they focused on an inquiry over a shorter period of time, and planned daily activities that got their students to meet and discuss online everyday in all three remaining activities.

Although the effect of site gives us an overall idea of the level of activity we can expect in an authentic context such as this one, the effect of group itself has far more impact on the participants. For obvious reasons, when two groups collaborate, and thus need each other's contribution to move forward, it is important to maintain a level of participation from each group that will keep all participants engaged (Riel & Levin, 1990). In each site however, there was a clear imbalance in the levels of participation, i.e., one group was contributing significantly more to the discussion than the other, even in cases where the groups had the same number of students. As discussed earlier, in this study, partner classrooms were more active than pilot classrooms, particularly in site A. Of course, since some groups were much larger than their partner (e.g., site A), we could argue that a lower number of notes per student in a bigger class could very well generate the same number of notes than a higher number of notes per students in a smaller class, thus resulting in equivalent contributions. It appears however that many notes repeat each other, especially if students do not get (or take) the time to read each other's notes and rarely work online, generating relatively poor contributions in terms of ideas. In general, the group effects on the number of notes per students reflected quite precisely difficulties expressed both by teachers and students with regard to their experience. Indeed, high contributors expressed how disappointing it was for them to have to wait for the other group to contribute.

Keeping aside the pilot vs. partner school factor, the imbalance in participation between collaborating groups created pedagogical problems as well as logistical ones. First, because the activities were structured around students' theories about a phenomenon to be explored, the students were asked to share their ideas with each other *before* going ahead with the inquiry. As such, they often waited after the other groups' theories, predictions and observations, before resuming with their inquiry process in order not to "give the answers" right away and spoil the fun. Thus, coordinating the activities between classroom collaboration and online collaboration was an important factor to attend to on the part of the teachers. Coordination is another important network participant structure identified by Riel and Levin (1990). If one group contributed notes that were considered as the "correct answers" by the other group, motivation dropped to carry on with the conversation, even though there were still things to learn. And waiting days on end for the other group to post their contribution was frustrating for the ones who were ready to move on to the next step, especially if this happened repeatedly.

As discussed above, in the present case the pilot sites contributed less than the partner schools. Because the pilot schools were the ones explicitly chosen to be part of the RNS, we expected that they would be the ones with the higher need to collaborate and thus would tend to be more active than their partner schools, who were less isolated and who usually had more students and thus were more self-sufficient. In this study however, this was not the case. One partner classroom had many fewer students and was indeed much more in need of interaction; its level of participation reflected just that. Meanwhile, the teacher in the pilot school left mid-year for maternity leave, which put a temporary halt to Activity 2. Fortunately, the second teacher was soon ready to continue, even though she was in her first year teaching. This change had great impact on her students' motivation with the online work, adding further delay in the activity, and resulting in added frustration for the collaborating group.

In Site B, the pilot classroom had fewer students than its partner classroom, but they were also from a much lower SES and their GPA was also much lower than the other group, from which we could infer that the reading and writing competencies were not at the same level and could have impacted their level of participation online. What is more, one classroom was shut down in September in this school because there were not sufficient students registered. This was a great blow to the school's climate in general, and to the students' motivation in particular.

In site C, the difference in participation is difficult to interpret. Both teachers have enjoyed working collaboratively for years now; they were both interested from the start in RNS and had had great experiences in the past with both the tool and collaborating online. They were eager to start this new school year but somehow one group stayed a little behind the other for the entire year. It may simply have been the result of a difference in students' interests and personalities.

The difference in student/computer ratios between classrooms is another factor that could have contributed to different participation levels across groups. For example, groups A3b had three computers but with only 5 students in all, so it was easy for each student to have some time alone at the computer. In comparison, group A3a had 3 working computers, including their teachers' laptop, but they were 24 students!

Technical difficulties were also common in site A for group a in the first four months. The teachers' computer was new but was not working properly, the computer lab was ill equipped and could not really be used, leaving the entire class with only 3 decent computers to work with. The IT people for this school did not take the teachers' complaints seriously until the researcher went on site and confirmed the poor state of the tools and network. Technical difficulties were also a problem in site C, mostly with the videoconferencing tool. This hindered the students' motivation to work together since they could not see each other from time to time, as first planned. Their teachers were not able to collaborate and plan their actions using this tool either, which was quite frustrating for them, being their third year as a RNS and still experiencing recurring technical problems. These problems could have had an effect not only on the participants' commitment to the task but also to their work as a whole if they experienced such problems during their planned time on the computers.

Finally, the teachers' own level of competence and skills with the Knowledge Forum itself (and their confidence in the school's network capacity) could have influenced the level of importance they might have attributed to having their students work online. What is more, we cannot ignore the fact that it is simply easier for a teacher with 5 students to include working at the computers to classroom activities than for another teacher working with 24 students.

The separate analyses for each site are generally consistent with the overall analysis. There were multivariate effects of group for site A and C, both showing greater means for group b than group a. What stands out again, is the high contribution of site A's group b, with its unusually small number of students. There was no group effect in site B. There was a multivariate effect of grade for site A but only univariate effects of grade in site C, on Activity 2 and total. Both effects signaled higher means for grade 6 students than for grade 5. In both sites A and C, there were Group × Grade interaction effects. In site B, there was only one multivariate effect, gender, with girls contributing more than boys to the database.

General Scaffold Support Use

The general overview of the use of scaffolds indicated that of the three sites, site C's use of scaffold supports was the most constant across activities. Site B used quite a lot of scaffold supports in Activity 1 but dropped considerably in Activities 2 and 3. Site A on the other hand, used the most scaffold supports in Activity 2 but dropped below Activity 1's mean in the last Activity. In general, a majority of students' notes included at least one scaffold support.

When we looked at which scaffold supports were mostly used at each site, we saw that *My theory* was by far the most used scaffold support. This result is positive because one of the pedagogical objectives of the project was to get students to share their ideas, their explanations of the explored phenomenon, in order to for them to express their initial conceptions. The high rate of use of this scaffold shows that they did share their ideas and explanations, whether they were correct or not, something they were rarely asked to do before. The other popular scaffolds were *My prediction* and *My observations* at all three sites, suggesting that the students found those scaffold supports meaningful and pertinent. We also know from the analysis of coherence that what some students might have labeled *theories* might very well have been *predictions* and vice versa which leads us to believe that coherent or not, the scaffold supports were used by the students more than ever before. A lot of questions were asked in site C, with a great use of *I would like to know* scaffolds. However, few *I relate* scaffold supports were used in each site.

The ultimate goal of this project being to help students understand and relate each step of an inquiry process, we would have liked to see greater use of the *I relate* scaffold support. This can be interpreted in two ways: either the students lacked the understanding of this scaffold and did not find it useful when they contributed notes or maybe, which is most probable, no emphasis was put on this part of the inquiry process: once the students proceeded with the experiment, they noted their observations but were not explicitly asked to go back to their original theories and reflect on the differences between what they had observed and what they expected to observe. From conversations with the teachers throughout the year, we tend to lean on the latter explanation. Students are motivated at the beginning of an experiment because they know what is coming. It may be easier to get them to write before doing the experiment. Once the experiment is done though, students are much less eager to reflect on what they have just observed. It becomes much harder for the teachers to get them to complete the inquiry process and go back on their initial theories and try to revise and explain what they have just observed. Students feel confident that they now know the "right answer" and they often do not feel the need to go back online. Without teacher intervention and insistence to revise their explanations, which implies teachers' belief that it is very important to do so, there is little chance that the students will on their own. And since most of the teachers enjoyed science activities with the students because the students were more active and had fun, judging from conversations and some interview data, more often than not, they probably did not insist on this important activity.

Statistical Analyses – Scaffold Support Use

As in the case of the analyses of the number of notes created, a significant effect of site was also reported in the analyses of the number of scaffold supports used per student. Site A (11.84) and C (11.39) had relatively similar means and both sites used significantly more scaffolds than site B (3.05). There was a significant effect of group, and here also groups b had a significantly higher mean (10.85) than groups a (6.60). A significant effect of grade was here too observed, grade 6 using more scaffold supports (9.16) than grade 5 students (7.23). Finally, there was a significant Site × Group interaction effect indicating a greater difference between group a and b in site A than in the two other sites, the same effect having be reported in the note creation analysis.

These effects are consistent with the note creation results, which was expected. Indeed, students were expected to use scaffold supports in their notes and they almost always did. The same explanations for the various effects thus apply.

Coherent Use of Scaffold Supports

As it was explained earlier, knowing *how many* scaffold the students used does not inform us on *how* they used them, i.e., whether or not they used them coherently to support their learning process. The analysis of coherence was conducted to that effect. In Figure 17 we compared the coherence level of each site across its activities. It showed that while site A was able to increase with time its coherence level, the two other sites did not. Site B dropped considerably from Activity 1 to Activity 3 (recall that Activity 2 included one scaffold only, be it coherent). Site C on the other hand started at a higher coherence level but gradually dropped its coherence across activities. Generally, we believe this was caused by lack of modeling on the part of the teachers in the online discourse. In group A3a, however, as we can see in Figure 18, there was constant improvement in the coherence level over the three activities.

A statistical analysis was conducted on each student's coherence level collapsed across activities the results of which were quite surprising. Indeed, we expected the sites that used the most the scaffolds and that created the most notes during the year to have gained a better understanding of the scaffolds leading them to have the highest coherence level. In reality, it was just the opposite. Site B, which generated far less notes and used far less scaffold supports during the year had the highest coherence level.

A first explanation may be that site B was also the site with the greater number of students missing from the dataset, i.e., students who used no scaffold supports and thus had no coherence level. This could have artificially increased the site's mean. Second, there was almost no modeling of the use of the scaffolds by the teachers in sites A and C, i.e., the teachers did not comment online on their students use of the scaffolds and in not doing so, did not show high and explicit expectations about their coherent use in the notes. In the first Activity at site B, however, the pedagogical consultant did model the scaffolds quite explicitly on the Knowledge Forum and the majority of the student notes contributed in this activity used the same scaffolds and in the same way, resulting in a high coherence rate for the majority of the students. In Activity 3 however, there was no such modeling and the coherence rate dropped significantly. The researcher modeled the use of the scaffolds in some occasions but her comments to that effect were not followed through online, and probably not in class either. However, in one group (A3b), a handout explaining each scaffold support was posted near the computers.

The analysis also showed a significant Site × Group interaction effect indicating differences of coherence levels between groups, which varied across sites. The biggest difference between collaborating groups was between groups A3a and A3b, where group b showed a significantly greater level of coherence than A3a when collapsed across all activities. Could this be the effect of that handout or was there teacher modeling of the scaffolds in the classroom which was not apparent online? We could infer that there was more modeling in group b because the teacher himself was more comfortable with the terms used and once said that he used the inquiry-based process in his practice before this project. While the other teachers did know of the inquiry process, they were not as clear about having used it in class during scientific activities prior to this project.

Pre- and Post-Test Results

One of the initial hypotheses suggested that the use of the Knowledge Forum could help students develop a better understanding of the inquiry process. Providing they used the scaffolds, the difference in participation between sites could result in a different understanding of the inquiry process, which should be reflected in the pre- and post- results on the inquiry process test. In other words, we believed that the sites, which used the tool in more activities, whose students created more notes, and who used the scaffolds more often, would use them with growing coherence and would thus better perform on the post-test.

What the analysis showed however, was quite different. There was no effect of site on the pre- and post-test analysis of variance, i.e., all three sites scored similarly (both tests collapsed). More importantly, there was no Test × Site interaction effect, i.e., all three sites scored similarly in their pre *and* post tests, suggesting that their different use of the tool, whether the note creation, use of scaffolds or coherence level, had no effect on the post-test scores.

What it did show was an overall effect of test indicating that the scores improved over time in all three sites. There was also a between-subjects Site × Group interaction effect indicating that the results collapsed across tests varied significantly between the groups depending on the sites. Among other things, group A3b, which created far more notes and used far more scaffolds than any other groups scored the highest mean of all. Site B groups both scored relatively the same while group C3b scored the lowest of all, even though it created more notes and used more scaffolds than both groups in site B. Furthermore, although site B's two groups scored much higher than both other sites on the coherence rate, their results on the post-test were not higher than either of the other groups.

Conclusion

The research question addressed in this first part of the results was: How can the use of prompts (i.e., scaffold supports) support the inquiry process in class and online help students better understand and put into practice an inquiry process, individually and collectively?

Evidence for the use of prompts online was found as the students in at least two out of the three sites contributed notes to the Knowledge Forum that almost always contained scaffold supports related to the inquiry process. Furthermore, although the scaffold supports were used more or less coherently, this coherence levels observed suggested that it could very well have been improved with further modeling on the part of the teachers.

However, judging from classroom observations and interviews with teachers from the different sites, evidence of classroom use of the prompts was rather scarce. In fact, many of the teachers mentioned that they should have insisted more on the use of scaffolds and their coherent use but we have observed that issues of coordination between groups and other technicalities drained much energy from the teachers, leaving less time and effort for pedagogical considerations.

Evidence of a better understanding of the inquiry process was obtained through the pre- and post-test data analyses that showed, among other things, a significant effect of test in the three sites. The results themselves, though, were not related to the level of participation (notes created or scaffolds used) as site B, who participated much less than both other sites, generated similar results on the pre- and post-tests on the inquiry process. Furthermore, the results themselves were rather low (nearing 50%) which illustrate a lack of insistence on the use and understanding of the different steps of the inquiry process on the part of teachers in almost every group. The results also reflect the fact that students and teachers in all three sites have mentioned having found the test very difficult.

During the interviews, many teachers stated that they believed their students better understood the inquiry process because for once, they had taken some time to reflect at every step of the process, instead of jumping to the hands-on experiment right away. Moreover, some of the students have shown a better understanding of the inquiry process through their casual use of the correct terms associated with inquiry such as theories, predictions/hypotheses and observations as they reflected on past activities during interviews. This contrasted with their understanding of the pre-test, which generated a lot of questions from students who did not know the word theory, for example. These observations also constitute evidence of the fact that the use of such learning prompts did help students to develop a better understanding of the inquiry process during authentic and collaborative inquiry-based activities.

The fact that almost every student contribution to the Knowledge Forum database included at least one scaffold support is clear evidence that the students did in fact put into practice such a process to support their collaborative learning process. In previous uses of the Knowledge Forum, none of these groups had used it for science activities and very few of them had used any kind of scaffold support in their notes. Classroom observations and interview data confirm that while the generally-accepted steps of a scientific inquiry were often presented at least once in the classroom, they were rarely used systematically during science experiments unless the didactic materials included them. This study provided an authentic context in which the use of a simple inquiry process could be used across activities as a cognitive tool to support student learning.

Finally, the individual data collected through the online tools as well as classroom observations and interviews with teachers and students from each site have informed our understanding of the collective learning processes that have emerged from the data presented in this section. In sum, the present study generated the results needed to answer our first research question.

CHAPTER 4 – RESULTS PART 2

In this second part of the results, the research question addressed is: how does the students' online collaborative problem solving translate into a deeper understanding of the phenomena explored?

To gather evidence to answer this second research question, we will discuss results from two different levels of analysis. At the macro-level, we will look at the level of explanation of the ideas expressed by students throughout all the activities conducted. At the meso-level, we will look more specifically at one activity that was conducted in two different sites and compare how the same activity generated different patterns in ideas and interactions in both sites.

To answer the third and final research question of this dissertation, a micro-level analysis will then consider some of the students' ideas and how they changed over time. This last analysis will conclude this chapter.

Macro-Level Analysis

Hakkarainen (2003a; 2003b; 2004) studied the emergence of a progressive-inquiry culture in computer-supported collaborative learning, as students from two classrooms used the prior version of Knowledge Forum. He analyzed students' written productions through qualitative content analysis (Chi, 1997). The basic unit of analysis of students' inquiry was the *idea*. This model included an analysis of the epistemological nature of the students' research questions that implied classifying research questions according to whether each was fact- or explanation-seeking in nature. This model also included the analysis of the epistemological nature of the knowledge produced by the students. In order to do so, Hakkarainen proposed a five-level scale starting from (1) separated, low-level facts to (5) explanation. The following table (Table 4) presents Hakkarainen's level of explanation scale.

Table 4

The Level of Explanation Scale (Hakkarainen, 2003a, p.207)

Rating	General description	Specific nature of knowledge produced
1	Separated, low-level facts	An idea consisting of a list or table of facts with hardly any integration or connecting linkages.
2	Partially-organized facts	An idea consisting of facts that were loosely organized together. The facts were stated without relating them to each other by means of causal or some other semantic connections.
3	Well-organized facts	An idea consisting of rather well-organized factual or descriptive information. Although the ideas did not explicitly provide an explanation, it was meaningfully organized and had the potential of facilitating understanding of the issue in question. However, the idea was descriptive in nature and did not rely on deeper explanatory relations.
4	Partial explanation	An idea represents an explicit attempt to construct an explanation, but explanation was only partially articulated. It was only an explanatory sketch that was not further elaborated. A partial explanation differed from a well-articulated explanation by being clearly in need for further clarification.
5	Explanation	An idea consisting of an explicit explanation, whether functional, empirical-physical or theoretical-physical in nature. Explanations contained postulation of common causes, cause-effect relations, reasons and other explanatory relations, or theoretical entities. In order to be classified as an explanation, an idea did not need to be formally correct; clearly identifiable intuitive explanations were regarded as explanations.

Method

For each activity, sites A and C students' notes on the Knowledge Forum were segmented into ideas, which were then coded according to Hakkarainen's level of explanation scale (2003a). Site B notes were excluded from this analysis because they used the Knowledge Forum much less during the year. Every question asked, whether from an adult or a student, was also coded according to Hakkarainen's model. Half of the data was coded by a second coder. Initial inter-coder agreement was low at 52%. After discussion, inter-coder agreement reached 81%.

The lengths of the discussion threads produced were also part of the macro-level analysis. Single notes were counted as "0 elaboration" and threads of 4 notes or longer were counted as "4-elaborations +". This generated a 5-point scale for the discussion threads observed in all of the activities conducted in sites A and C.

Results

Results from the discourse analysis using Hakkarainen's model for site A are presented in Table 5.

Table 5

Frequencies and Percentages of Students' Productions (Site A)

	Activity 1		Activity 2		Activity 3	
	f	%	*f*	%	*f*	%
Group A3a						
Research Questions	0	0.00	4	25.00	2	9.09
Content ideas	56	100.00	12	75.00	20	90.91
Total group A3a	56	100.00	16	100.00	22	100.00
Group A3b						
Research Questions	3	13.64	4	8.33	2	10.53
Content ideas	19	86.36	44	91.67	17	89.47
Total group A3b	22	100.00	48	100.00	19	100.00
Total						
Research Questions	3	3.85	8	12.50	4	9.76
Content ideas	75	96.15	56	87.50	37	90.24
Grand total	78	100.00	64	100.00	41	100.00

Both groups in site A generated much more content ideas than research questions. The total ratio was almost 9:1. In Activity 1 and 3, group A3a generated more content ideas than group A3b. Since there were 5 times more students in A3a, this was expected. Table 5 also shows a gradual decrease in the total number of content ideas generated across activities. This gradual decrease is consistent with the fact that group A3a was not as active and quick to respond as group A3b during the year. As mentioned before, there was a general discrepancy in student participation between groups: in Activity 2, the five group A3b students generated as much as 44 content ideas while 24 students in group A3b generated as little as 12. This discrepancy in student participation had an effect on group A3b students' motivation over time and certainly explains their lower contribution of ideas in Activity 3 which was not offset by additional group A3a ideas. This may have led to the general decrease in the number of content ideas generated across activities.

Figure 19 illustrates the distribution of content ideas generated in each activity across Hakkarainen's five levels of explanation. The figure shows a general increase in the levels of explanation across activities i.e., more higher-level ideas are generated across activities. When we collapse level-3 ideas and above for each activity, we can confirm this general increase with cumulative percentages going from 20.78% (Activity 1) to 66.07% (Activity 2) to 89.19% (Activity 3). It seems therefore that if the number of content ideas tended to decrease across activities, the complexity of those ideas tended to increase, which is quite interesting. Could this be because the lower-achieving students were the first to stop contributing their ideas to the database or because as students got more comfortable with the tool and the new classroom practices, they were more able to focus on their notes, and as a result, contributed higher-level ideas?

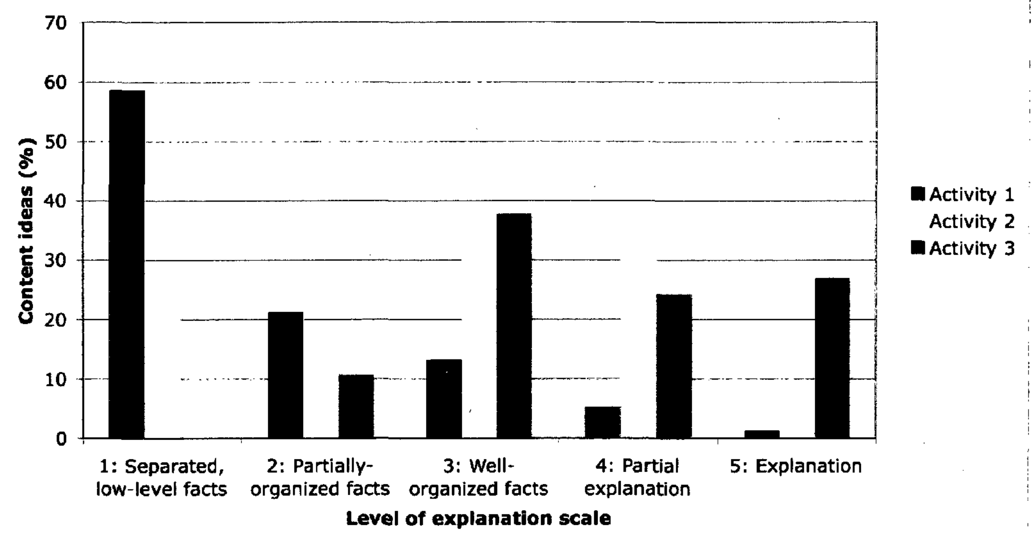

Figure 19. Distribution of Site A content ideas across levels of explanation.

The types of research questions generated by site A students and adults are illustrated in Figure 20. In Activities 1 and 2, fact-seeking questions were almost twice as much frequent as explanation-seeking questions, but this tendency was reversed in Activity 3. Looking back on the very high proportion of content ideas at level-3 and above in Activity 3, we might wonder if the nature of the teacher directives for the inquiries may have influenced the level of ideas generated. Indeed, in Activity 3, all of the inquiry-based directives were explanation-seeking questions.

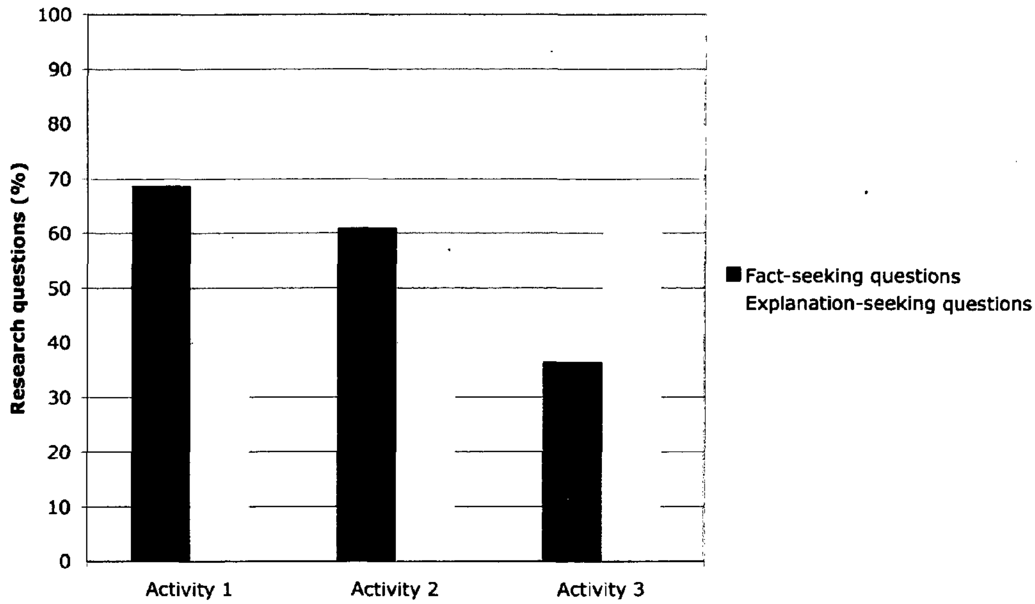

Figure 20. Distribution of Site A research questions (adults included).

Results from the discourse analysis using Hakkarainen's model are illustrated for site C are presented in Table 6.

Table 6

Frequencies and Percentages of Students' Productions (Site C)

	Activity 1		Activity 2		Activity 3		Activity 4	
	f	%	*f*	%	*f*	%	*f*	%
Group C3a								
Research Questions	1	4.17	2	10.00	0	0.00	6	21.43
Content ideas	23	95.83	18	90.00	33	100.00	22	78.57
Total group C3a	24	100.00	20	100.00	33	100.00	28	100.00
Group C3b								
Research Questions	0	0.00	6	10.71	1	5.26	7	16.28
Content ideas	44	100.00	50	89.29	18	94.74	36	83.72
Total group C3b	44	100.00	56	100.00	19	100.00	43	100.00
Total								
Research Questions	1	1.47	8	10.53	1	1.92	13	18.31
Content ideas	67	98.53	68	89.47	51	98.08	58	81.69
Grand total	68	100.00	76	100.00	52	100.00	71	100.00

In site C also, more content ideas than research questions were generated (see Table 6). In Activity 2 and 4, students asked much more questions (8 and 13) than in Activity 1 and 3 (only 1 in both). In Activity 4, a relatively high percentage of 18.31% research questions leaves us wondering if it may be related to the very high proportion of level-1 ideas.

Across activities, the number of content ideas generated was rather steady. This is consistent with the number of notes created. Few notes could have generated a high number of content ideas and research questions, however it was not the case here. Although both groups had the same number of students, group C3b generated more content ideas in Activities 1, 2, and 4 than group C3a, which is also consistent with note creation data.

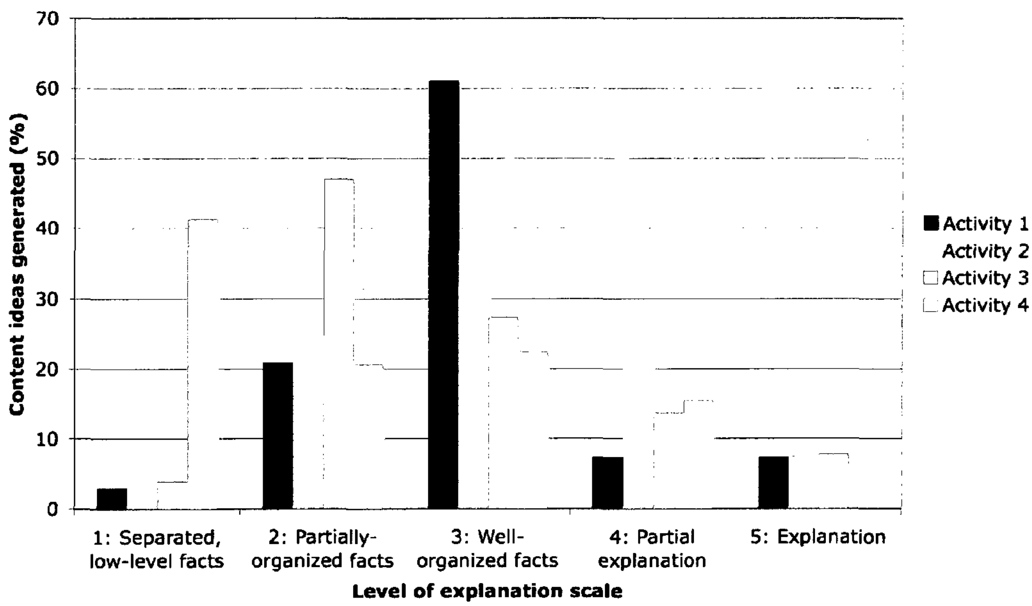

Figure 21. Distribution of Site C content ideas across levels of explanation.

Figure 21 illustrates the distribution of the content ideas generated in each activity. Here, the figure shows a general decrease in the level of ideas with time: fewer higher-level ideas are generated across activities. When we collapse level-3 ideas and above for each activity, we can confirm this decrease with cumulative percentages going from 76.12% (Activity 1) to 70.59% (Activity 2) to 49.02% (Activity 3) to 37.93% (Activity 4).

Figure 22 illustrates the distribution of research questions across activities. Activities 2 and 3 generated more explanation-seeking questions while Activities 1 and 4 generated more fact-seeking questions, from both students and adults.

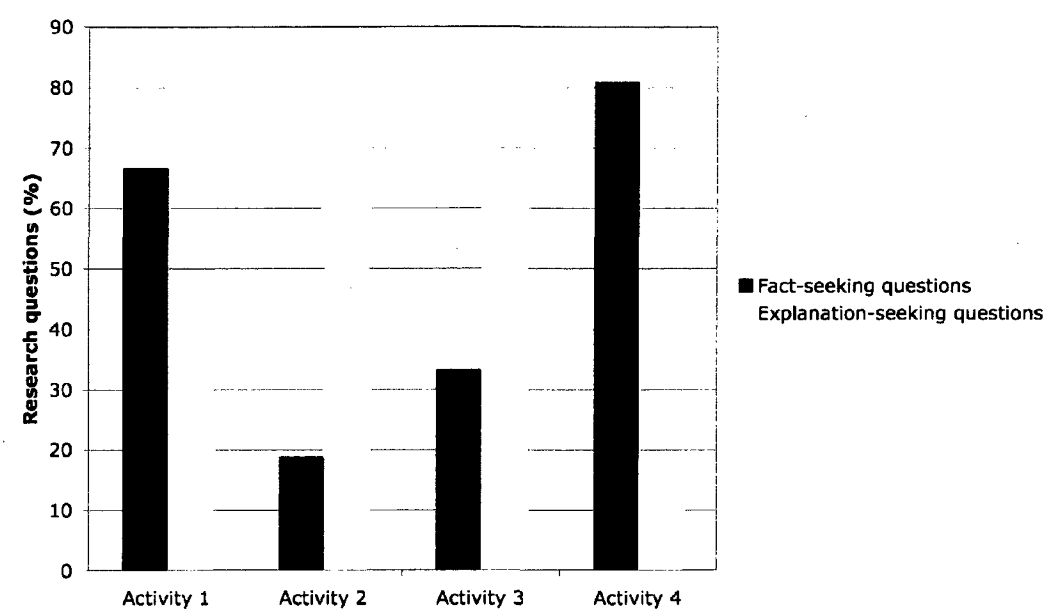

Figure 22. Distribution of Site C research questions (adults included).

If in site A, all of the inquiry-related directives in Activity 3 were explanation-seeking in nature and the level-3 and above content ideas generated were very high at 89.19%, the relationship between the types of directives and the content ideas generated is even more convincing in site C. Indeed, as the proportion of content ideas at level-3 and above dropped across activities, the proportion of explanation-seeking inquiry-related directives also dropped from 100% (Activity 1), to 75%(Activity 2), to 60%(Activity 3), and to 20%(Activity 4). Since students naturally tend to answer their teachers' questions, when the teacher directives themselves are mostly fact-seeking questions, it is not surprising that the majority of content ideas generated to answer those questions should be lower- rather than higher-level ideas. Therefore, the teacher's choice of inquiry activities should take this into account if their objective is to help students develop explanations of scientific phenomena rather than discuss facts about the phenomena.

Discussion Threads

The length of the discussion threads can give us a general idea of the type of discussion that is generated in the Knowledge Forum. Indeed, we can hardly argue that a rich collaborative discourse is happening when the discussion threads are very short i.e., 1- to 2-elaborations long. In order for rich interaction between students to take place, there is a need to go beyond the traditional classroom I-R-E sequence where the teacher asks a question (Initiate), a students answers (Respond) and the teachers gives some kind of evaluation of the students' answer (Evaluate) (see Cazden, 1988, 2001; Lemke, 1990). In the context of an online environment, while it is not rare to see student elaborate directly on their teacher's note, the idea is to get students to elaborate on each other and generate discussion threads that manifest their collaborative progressive discourse. For this reason, the discussion threads in sites A and C were analyzed. Figure 23 illustrates the length of the discussions threads observed across activities in site A.

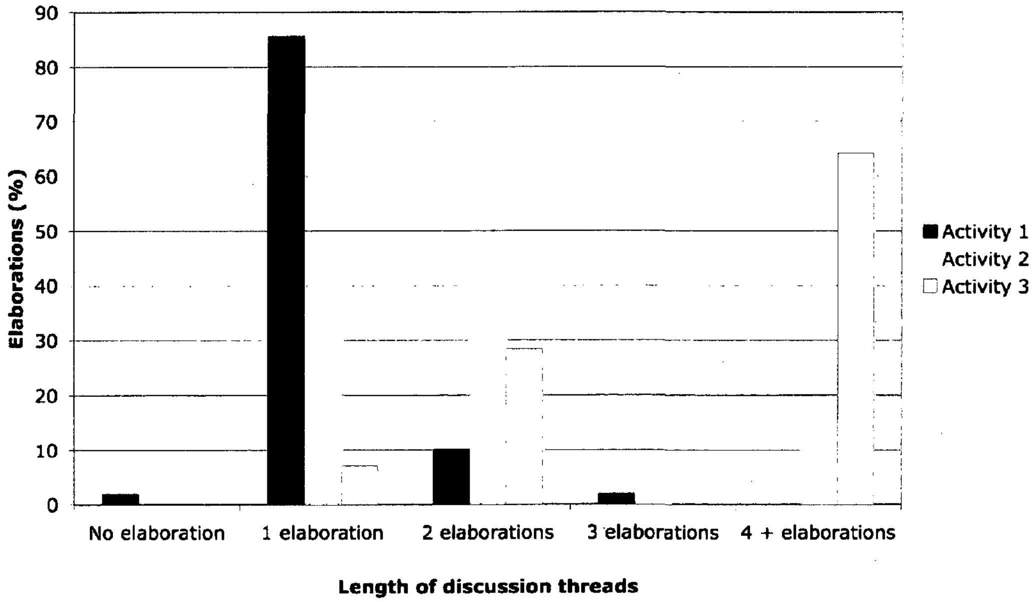

Figure 23. Relative lengths of Site A discussion threads across activities.

As we can see from Figure 23, while Activity 1 mostly generated very short threads, Activity 2 generated some longer threads. In Activity 3 more than half the threads contained more than 4 elaborations. In site C however (see Figure 24), the great majority of the threads were only 1-elaboration long i.e., student notes that were direct answers to the teacher's inquiry-related directive that did not generate further elaborations.

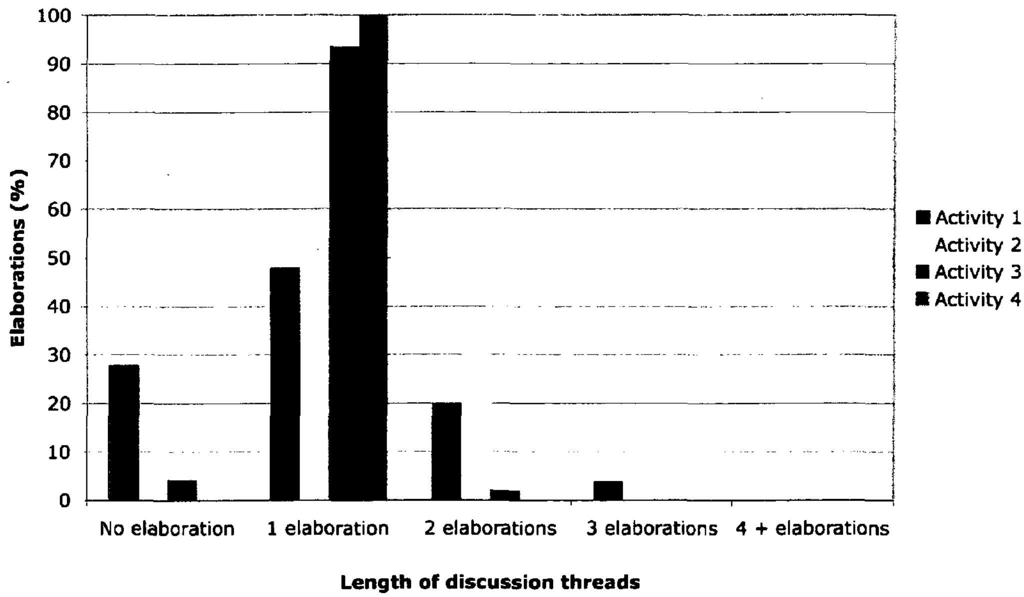

Figure 24. Relative lengths of Site C discussion threads across activities.

Moreover, the data show that there were longer threads when adults contributed to the discussion (i.e., when adults generated notes in the database). Site A shows longer threads and in most of them, there were notes contributed by the researcher and the teachers. In site C where threads were much shorter, the teachers were very active online but they used annotations instead of notes to comment on the student's notes. Site C students also used annotations profusely to comment on each other's notes (on their spelling but also on their ideas) but hardly elaborated on each other's note. It is as if they did not value their comments as worthy of elaborations per se, but as if they felt very comfortable to annotate their peers' notes.

As was noted before, it seems that students naturally tend to address their notes primarily to the teacher, i.e., as a direct answer to their teachers' directive. If an adult elaborates on their note, they will build on that elaboration, which lengthens the thread, but otherwise, they do not elaborate on each other. Teacher mediation to that effect is clearly required.

The relationship between the types of research questions generated by students and adults throughout the activities, including the directives themselves, and the levels of explanation reached by student content ideas is quite interesting. Whereas we cannot claim the former is causal to the latter, the relationship observed in both sites certainly increases the interest of this result. While it is not that surprising in itself – after all, we expect explanation-seeking questions to generate explanation-oriented answers – we must keep in mind that the ideas generated in the Knowledge Forum were not systematic answers to the questions asked. Indeed, a lot of the questions were generated by teachers and students as reactions to the content ideas contributed to the database. Unfortunately, a lot of these questions were left unanswered.

As for the discussion threads, again the results confirm that students prefer to answer the teachers' questions rather than elaborate on each other's notes. Unless teacher mediation includes specifications regarding student reading their peers' notes and elaborating on each others' notes, it is naïve to think that it will happen just because the online environment makes it possible. We further believe that this may be a direct reflection of the usual classroom discourse i.e., that students are used to answer their teachers' questions and directives and much less to question and elaborate on each others' ideas. This, of course, is largely a question of classroom culture (see Bielaczyc, 2001; Brown & Campione, 1994).

Meso-Level Analysis

As stated earlier, one activity conducted was the same in both sites. The topics explored in this inquiry were buoyancy and relative density and the central experiment involved exploring ways to make an egg float while keeping it intact. While many students thought about making a boat on which to put the egg, others explored different fluids and their relative density. This activity was conducted at different times during the year and in very different classroom contexts: in site A, this was Activity 3, the last activity conducted, with low student motivation and low overall satisfaction of Teacher A3b; in site C, this was Activity 2, with very high student motivation and high satisfaction of both teachers. However, in both sites, the activity generated higher-level ideas than was observed in the other activities.

In site A, 89% of the content ideas generated were coded as level-3 ideas or higher. As much as 27.03% of the content ideas were explanations, 24.32 % were partial explanations and 37.84% were coded as well-organized facts (Figure 19). In this activity, groups A3a and A3b generated similar number of content ideas (24 and 27), even though the groups were of very different sizes (Table 5). Three out of the four questions generated by students alone were explanation-seeking questions; when we include the adults' questions, 63.33% of the 30 questions asked were explanation-seeking questions.

In site C, 70% of the content ideas generated were coded level-3 ideas or higher. The students' content ideas generated represented 32.35% well-organized facts, 29.41 partial explanations and 8.82% explanations (Figure 21). In this activity, although both groups are the same size in terms of students, group C3b contributed much more content ideas (50) than group C3a (18). As much as 81.08% of the 37 questions were explanation-seeking questions and the 8 questions generated by students were all explanation-seeking questions (Table 6).

On the one hand, the discussion threads in site A were longer and adults contributed more notes. On the other, site C generated much smaller threads but students and teachers added a lot more annotations to share questions, ideas and comments.

Pre- and Post-Test Results

The students completed a test on the concepts of buoyancy and relative density before they engaged in the activity and once it was finished. Only 38 students completed both the pre- and post-tests. Group A3a students were not given the pre-test and therefore were not included in the repeated measures ANOVA. The independent variables in this analysis were gender (19 boys, 19 girls), site (4 in site A, 34 in site C), group (17 in group a, 21 in group b) and grade (16 grade 5 students, 22 grade 6 students). The dependent variable was the test score, which consisted of five questions each earning a maximum of three points[18].

The analysis showed a significant effect of test ($F(1, 27) = 6.160, p = 0.20$). As expected, post-test scores ($M = 9.073, SD = 0.547$) were higher than pre-test scores ($M = 7.064, SD = 0.455$), although they were both rather low. There was also a significant between-subjects effect of site ($F(1, 27) = 8.057, p = 0.09$) indicating that site A students scored significantly higher ($M = 10.083, SD =$

[18] See Appendix E for the test and Appendix F for the rubric of scores.

1.039) than site C students ($M = 7.313$, $SD = 0.351$). No other significant effects were found.

To include the results from group A3a, we then conducted an ANOVA on the post-scores only. The independent variables in this analysis were still gender (26 girls, 36 boys), site (25 in site A, 37 in site C), group (40 in group a, 22 in group b) and grade (26 grade 5 students, 36 grade 6 students). This second analysis showed a significant Site × Group interaction effect ($F(1,47) = 5.835$, $p = 0.020$) which indicates significant differences between the post-scores obtained in different collaborating groups. Indeed, group A3a students scored lower ($M = 7.667$, $SD = 0.763$) than group A3b students ($M = 10.667$, $SD = 1.701$), while group C3a students scored higher ($M = 9.687$, $SD = 0.773$) than group C3b students ($M = 7.292$, $SD = 0.807$). No other significant effects were observed.

The results of the post-test scores analysis are somewhat surprising. Indeed, while group A3b was much more productive online then their partner group (higher number of content ideas in proportion to the number of students), which could explain better scores on the posttest, the opposite happened in site C. Group C3a generated fewer content ideas than group C3b but scored higher on the posttest. Since both groups had similar pre-test scores, the discrepancy in the post-test scores lead us to believe that something different happened in the classroom, probably once the online activity was finished. One hypothesis is that Teacher C3a realized that her students had not participated as much as she had planned and took some extra classroom time to go over the concepts before they completed the test. After verification with Teacher C3a, it appears that this may have been the case; although she does not remember exactly *when* she revised the concepts with her students, Teacher C3a is positive they were discussed thoroughly in class.

Discussion of the Results

The results presented above have provided evidence to the effect that the students' online collaborative problem solving process did translate into a deeper understanding of the phenomena explored. Indeed, the macro-level analysis of the activities conducted in sites A and C have shown that students were able to generate content ideas to answer inquiry-related questions and that these content ideas could take the form of separated, lower-level facts and but also genuine explanations. The results have also shown that specific teacher mediation, in the classroom as well as online, could bring students to generate higher-level content ideas, especially when prompted by explanation-seeking rather than fact-seeking questions. Evidence was also shown that when the didactic material does not include enough explanation-seeking questions, additional teacher mediation to that effect should be considered in order to bring students to generate explanations about the phenomenon and not only discuss facts related to it.

The macro-level analysis of the discussion threads has also provided evidence that longer threads tend to indicate richer interactions between participants and should be encouraged. Indeed, students do not tend to elaborate naturally on each other's notes unless they are specifically required to do so. When adult or teacher mediation takes form online through notes rather than annotations in the students' notes, longer threads have been observed. Students are naturally inclined to answer directly the teacher's questions and notes: this leads us to believe that it is a natural reflection of the I-R-E sequence often observed in classroom discourse. A tool like the Knowledge Forum has the potential to transform this sequence but in order for more interactions between the students to take place, teacher mediation to that effect must shape the new practice. For example, students may be asked to answer the teacher's directive *and* elaborate on a student's note by either contributing a different content idea or by generating a new research question that would help the group to progress in their understanding of the phenomenon.

In addition, the meso-level analysis of one of the activities conducted in both sites has confirmed that high-level content ideas are related to a high proportion of explanation-seeking rather than fact-seeking questions and that it should be encouraged. It also confirmed the importance of online teacher mediation to scaffold students' generation of higher-level content ideas (Coleman, 1998; Palincsar, 1998; Pea, 2004; Wegerif & Mercer, 1996, 1997) in both sites. However, as we will further discuss in the next section, many questions were left unanswered, unfortunately.

The pre- and post-test analyses have shown that the students from both sites scored significantly higher on their post-test than on their pre-test, which indicates that they did develop a deeper understanding of density and buoyancy while working collaboratively in the Knowledge Forum. The analysis of the post-test results has also shown that there was a Group × Site interaction effect indicating that one collaborating group scored better than the other in both Sites. In site A, the group who generated the more content ideas per student scored higher on the post-test. In site C, the opposite was observed, i.e., the group who contributed the fewer number of ideas scored higher than its partner. This has led us to believe that extra time to review the concepts may have been taken in class as a way to offset the lack of participation from this group. Just as we believe that written collaborative problem solving in the Knowledge Forum can enrich classroom learning, we believe that in this case, classroom discussion may very well have enriched this group's online learning context.

In sum, the present study generated the results needed to answer our second research question.

Micro-Level Analysis

The pre- and post-tests did not only give us an idea of students' better understanding of buoyancy and relative density before and after they collaborated online as they conducted their inquiry, they also allowed us to identify some of the students' conceptions and understanding of the phenomena which complements the ideas expressed in the Knowledge Forum. Indeed, whereas the notes contributed online revealed some of the students' ideas, their individual answers on the pre- and post-tests revealed even more ideas that will in turn contribute to our understanding of their learning process.

The present section describes some of the ideas expressed by students as they reflected on the topic of buoyancy and relative density. Using these two complementary sources of student discourse, we will attempt to find evidence of their collaborative learning process. Throughout, we will also try to find evidence, if any, of conceptual change. If evidence of conceptual change should emerge from this micro-level analysis, we will attempt to describe if and how this specific collaborative learning context shares similarities with Roschelle's convergent conceptual change model. This should allow us to answer the third and last research question of this dissertation: can this particular collaborative problem-solving context lead to conceptual change? If so, what are the characteristics of students' conceptual change process in this context?

In this section, four excerpts from the two sites will be described. The excerpts were selected based on the length of the discussion threads, on the ideas expressed and because they showed more than in others some evidence of conceptual change whether in the notes themselves or judging from the answers of the authors in their pre- and post-tests. Accordingly, each description will detail initial ideas from pre-test, student written discourse from notes and ideas from post-tests. Each description will then present whether or not evidence of conceptual change was found, describe the learning process, and relate it to theories of learning and conceptual change discussed in the theoretical framework.

Discussing Buoyancy – Excerpt 1[19]

In this first excerpt, the students discussed why some objects float while others sink. This question was asked in the test as well as online. For authenticity purposes, the students' notes were left untouched and contain grammar as well as spelling mistakes. English translations follow in the analysis and are also available in the Appendix.

1.2 Students 1, 2 and 3:
L'eau fait son rôle et essaie de retenir l'objet à la surface et quand l'objet est rond l'eau ne pourra pas le retenir car il n'a pas de grande surface. Plus c'est rond et lourd plus ça coule.

La densité est que deux objets du même poids un plat et un rond. Le rond reste à la surface et le plat coule. C'est grâce à la densité. plus que l'objets est rond et lourd il va couler. plus qui est lourd et plate plus que l'eau ne pourra pas le retenir.

[19] For the English translation see Appendix G.

1.2.1 Researcher:
OK donc selon vous, si l'objet est plat, il va couler. Mais pourquoi un radeau plat arrive-t-il donc à flotter?? Vous avez une partie de la solution... Expliquez-moi le rôle de la densité dans tout cela...

1.2.1.1 ; Students 1 and 3:
Un radeau ne coulerat pas parce qu'il a une grande surface donc l'eau peut le retenir. La densité désigne le poids et la surface de l'objet. Elle déside si l'objet coule ou pas.

1.2.1.1.1 Researcher:
Peux-tu m'expliquer en quoi la densité influence si l'objet coule ou pas? Tu as beaucoup d'éléments de réponse dans ta note déjà...

1.2.1.1.1.1 Student 1:
Moi je pense que plus que l'eau est dense plus que l'objet va flotter et moins que l'eau est dense plus qui va couler.

In the first elaboration (1.2), the students explain that water will keep the object afloat but if the object is round, the water will not be able to retain it because the surface of the object will not be big enough. The students add that the more the object is round and heavy, and the more it sinks. In the second part of the note, the students explain that density means that if you have two objects that weigh the same, and one is flat and the other is round, then the round one floats and the flat one sinks. This is because of density. The rounder and heavier the objects are, the more they will sink. They add that the heavier and flat an object is, the less likely water will be able to retain it.

One can see in this note that the students' conception of buoyancy is not yet coherent since in one sentence, the round object sinks and in the next it floats while the flat one sinks. However, we can also see that the underlying idea here is the fact that the *surface* of the object plays a role in its buoyancy. Indeed, here water *plays a role to support or retain* the objects afloat and if the object meets certain criteria (light enough, flat enough, round enough) then the water will be able to 'play its role' and keep it afloat.

This first note is consistent with some of the ideas expressed by one student in his pre-test. Indeed, Student 1 explains buoyancy by the surface of the object in his pre-test as well as the presence of air in the object that would explain why it should float. Student 3 believes that density means the objects' weight and that this is what determines whether it floats or sinks. Student 2 did not complete the pre-test.

I should mention here that this group of students completed with great success a first activity on gravity and free falling in their classroom at the beginning of the year. During this activity, the students explored how, in some instances, the surface of a falling object influences the speed at which it falls. All the students participated in the development of a prototype that could enable them to drop an egg from a 2-meter mark and not break it, which included the development of a parachute-like device. All of the students were able to explain correctly the phenomenon of gravity, air resistance, and the role of mass and surface when interviewed a few weeks after the activity. I believe that their very complete understanding of these phenomena was directly transferred to their (or at least Student 1's) initial conception of the present problem: in this case, the water takes on the role of air resistance ('*the water supports the objects*') and buoyancy (or lack thereof) replaces the idea of the egg's slowed free fall. This could also explain the student's idea that the surface of the object influences its buoyancy: after all, the egg's parachute had to have a large surface in order for it to be sufficiently slowed down by air resistance.

This is a good illustration of Smith, diSessa and Roschelle's (1993) argument that students build more advanced knowledge from prior understanding.

In this particular example, we could say that students' elements of knowledge from their prior understanding of gravity and air resistance were sufficient for them to explain their understanding of buoyancy at this point. As claimed by these authors, this is consistent with a constructivist perspective on learning and the consideration of understanding as a system of knowledge elements (or *p*-prims) and therefore implies a view of conceptual change as a gradual process.

In the second elaboration of this thread (1.2.1), the researcher builds on the students' idea that a flat object should sink and asks, if that is the case, why does a raft float? The researcher reminds them that they already have one part of the solution and then asks them to explain the role of density in this phenomenon. The researcher's role here was to scaffold the students' learning process by pointing out one of their ideas and asking them to elaborate it further while giving them some ideas (i.e., density) that could help them out.

In the third elaboration (1.2.1.1.), students 1 and 3 reply that a raft will not sink because its surface is big and therefore, the water will be able to support it. Here, the students clarified their explanation of the role of surface. Indeed, in their first note, they proposed two contradictory explanations, but in this note they confirm that they believe the water will be able to support an object with a great surface *just as air resistance is able to slow down a falling object attached to a big and light enough surface.* What is more, in this same note the students describe density as the weight and surface of an object (rather than its mass to volume ratio). They add that "*density decides if the object floats or not*".

Again, I believe that this is an illustration of the knowledge-in-pieces model proposed by Smith and colleagues (1993). Indeed, the students are aware that density plays a role in buoyancy. However they do not clearly understand what density really is, although they seem to know it is a characteristic of the object. Using prior elements of knowledge or *p*-prims, namely the surface and mass of objects and their relationship to gravity and air resistance, they are able to transfer these *p*-prims to this new situation. In the case of a raft, their knowledge-in-pieces of buoyancy is quite successful. Indeed, the raft may be heavy but its surface is quite important and it is indeed able to 'sit' quite well on the water's surface and not sink as a rounder object of the same mass would.

Unfortunately the discussion thread stops here, the last note having been posted at the end of May, well after the beginning of the activity two months earlier. Less than a week later the students completed the post-test. Student 1's answers further show evidence of a 'knowledge-in-pieces' conception of buoyancy: in one answer, he explains that objects float if there is air in the object and if the surface of the object is important. In another answer, he states that the denser an object is, the more it sinks but in the last question, he believes that a liquid that is heavier (not denser) will fall at the bottom of a container and a lighter object will float on it. Student 3's answers to the post-test included the term density as an explanation for buoyancy but it also included her definition of density as the size and length of the object, here too showing evidence of a partial or incomplete conception of density and of its role in buoyancy. This provides further evidence of the student's gradual shift from particular conceptions to complex knowledge systems, as argued by Smith and colleagues. This first excerpt illustrates well how students construct their vision of the world from what they know and in this case, how they were able to explain, although not in a completely scientifically-accurate manner, their understanding of this particular phenomenon.

Since there were no more interactions in the forum after that note, traces of the students' learning process did not show evidence of a greater shift from their initial conception to a more complex understanding of buoyancy that would have included additional elements of knowledge proper to this phenomenon. In this sense, it did not show evidence of conceptual change regarding buoyancy itself but it did provide us with evidence of the use of prior knowledge to grasp new phenomena.

Discussing Buoyancy — Excerpt 2[20]

1.6. Students 4, 5, 6 and 7:
Student 4: *Moi je dit que c'est parce que l'objet qui flotte contien de l'air.*
EX: Si tu remplis une bouteille d'eau au complet jusqu'au bord avec son bouchon elle coulera car ele ne contien plus d'air. Mais si tu remplis la bouteille jusqu'à 4 cm du bord seulement le 4 cm pas d'eau mais d'air va faire flotter la bouteille mais la partie avec l'eau elle sera couler...la partie avec l'air elle flottera parecsempe... et si tu mais une bouteille vide (toujours avec le bouchon car pas de bouchon l'eau se remplis et fait sortir toute lair alors quand lair sera toute sortie alors biensur la bouteille va couler) va flotter toute au complet hors de l'eau.Et je dit que il n'y a aucun raport avec le pois et/ou la grosseure de l'objet

Students 5, 6, and 7:*On trouve que les choses plus lourdes comme les roches ça coulent et les choses plus légères flottent.*

1.6.1 Researcher:
Si je vous comprends bien, les objets lourds coulent et les objet légers flottent... Mais pourquoi de gros bateaux réussissent-ils à ne pas couler, alors?

1.6.1.1 Student 6:
Parce que il ya des l'air dans le Bateau

1.6.1.1.1 Researcher:
Peux-tu m'expliquer ce qui fait que l'air dans le bateau lui permet de flotter sur l'eau même s'il a une masse très importante?

In the first elaboration of this thread (1.6), the students suggest two explanations. Student 4 writes that she thinks that objects float if they contain air.

[20] For the English translation, see Appendix H.

She then supports her argument with an example. In this example, a closed bottle full of water will sink because it does not contain any air. However if you almost fill the bottle up, leaving the remaining 4 cm empty, this student says the bottle will float because of the air contained in the empty space left in the bottle. She further states that the part of the bottle containing water will sink but that the empty part will float. The student adds that if you empty the bottle completely, (while keeping it closed because without the cap the bottle will fill up with water and sink) then it will completely float. She ends her statement by saying that the weight and/or size of the object have nothing to do with this. Her three teammates think otherwise. They believe that heavier objects sink and lighter objects float.

This group did not complete the pre-test, unfortunately, but we will consider these two different theories of buoyancy as their initial conceptions. We claim that this first note could be related to the first step of Roschelle's process of convergent conceptual change (1992). In this example, the collaborating students are constructing and sharing two different "deep-featured" situations at an intermediate level of abstraction from the literal features of the world, i.e., a first situation relative to the presence of air in the object to explain buoyancy and a second situation relative to its weight. Student 4's example goes a step further in the process by displaying a series of utterances in reference to the situation described i.e., the different states of the bottle and whether it will float or not.

Following this note, the researcher in note 1.6.1 builds on the second explanation stated. She asks them if heavy objects sink and light objects float, then why can big boats float?

In note 1.6.1.1. Student 6 shortly responds by saying that a boat floats because it contains air. This answer would not be surprising coming from Student 4 whose own explanation of buoyancy was constructed around the idea of air in an object. However, Student 6 did not agree with her colleague's explanation at first. We could infer that Student 6 was either convinced by Student 4's explanation or influenced at some other point by someone or something else, in the classroom perhaps, to adopt the same explanation. In any case, at this point, this student has adjusted her constructed situation to include Student 4's situation. We could interpret this as the manifestation of the interplay of metaphors in relation to each other in reference to the constructed situation, Roschelle's second step of the convergent conceptual change process. In this case, Student's 6 is relating Student 4's constructed situation and example of the bottle to her repaired deep-featured situation and example of the boat (heavy but contains air).

According to Roschelle's model (1992), convergent conceptual change also relies on an iterative cycle of displaying, confirming and repairing the constructed situations. Unfortunately, there are no additional traces of such an iterative cycle in the Knowledge Forum following these notes. Neither are there traces of the fourth and last step of Roschelle's proposed process, which consists of the application of progressively higher standards of evidence for convergence.

Three hypotheses emerge: (a) the iterative cycle happened in the classroom around the computer, and thus no written traces were kept, (b) the iterative cycle occurred in the classroom with other students or during a teacher-led discussion, after the online work was considered finished or, (c). the iterative cycle did not happen at all and the students did not converge toward a common understanding of buoyancy.

In this second excerpt, the beginning of the discussion thread showed great promise in terms of discussing two different explanations of a phenomenon. Unfortunately, the opportunity to support the students' collaborative learning process to the point of convergent conceptual change was not intentionally provided either because the opportunity was not recognized or simply because other external factors disrupted this process. In any case, we know from the interviews that no class time was provided to go back to their initial notes once the experiment was finished. When the students did go back to the forum after the experiments, they shared their observations but were not specifically asked to relate what they had observed to their initial theories other than to say that they were "right or wrong". We believe that if that had been the case, we would have had the opportunity to see what those students thought of their initial theories after having conducted the rest of the inquiry. Although the teachers were often reminded of the importance of this step in the activity, this seems to have not been possible. We will discuss this further later.

In any case, the post-tests answers are interesting in the sense that they show some departure from the students' initial knowledge about buoyancy as well as no departure at all, a situation from which emerged most of the conceptual change research to begin with. Student 4 mentioned density in almost all of her answers to the post-test and scored 3 points on them all except for the last question, which was by far the most difficult for everyone. She no longer mentioned the presence of air as an explanation of buoyancy. Student 5 still believed that heavier objects sink and lighter objects float. Student 6 mentioned density in the post-test but was not very articulate about it compared to other students. Finally, Student 7 talked about *masse volumique*[21] in one of his answers but was not able to explain what density was and he did not answer the last question.

The interviews with their teacher and two teacher-added questions in the post-test show that these students spent some classroom time on the notion of *masse volumique* . Because there was no mention of *masse volumique* in the Knowledge Forum but many in the post-tests, this classroom discussion occurred after the online activity. In any case, it seems that the time devoted to this particular concept was fruitful because a lot of the students were able to answer correctly the additional questions and seemed to relate the value of the *masse volumique* of an object to whether it floated or sank in water. However, they still had difficulty answering the rest of the test. This is another illustration of diSessa's knowledge-in-pieces: students knew how to calculate the ratio and they also knew that if the ratio is greater than 1 it floats and if the ratio is smaller than 1 it sinks, but they still could not explain the concept of density nor the relationship between buoyancy, the relative density of an object, and that of the liquid in which it is submerged, the last question of the test.

Discussing Buoyancy — Excerpt 3[22]

This discussion thread addresses the inquiry-related directive: "Two identical sheets of aluminum foil are formed into two balls, one is very compacted

[21] Quasi-synonym of relative density in French that means the ratio of the mass by volume.
[22] The English translation is available in Appendix I.

and the other much looser. Are the balls going to float or sink?" The following excerpt includes 5 elaborations on the teacher's directive, only two of which generated one elaboration[23].

2.1. Student 8: *La boule lache va flotter et la boule serré va coulé.* *Mes observations on an eu raison*
2.2 Student 9: *on avait pas raison la boule lâche a flotter et la boule serrée a couler.*
2.3 Student 10: *la boule compactée a callée parce que il navait pas d'air dedans et l'inverse pour l'autre.*
2.4 Students 11, 12, 13 and 14: *la boule qui etait chifoner ne coulai pas il avai boucoup d'aire dedans et celle qui etait plate avais moin d'aire dedans et elle etais plate et sa couler vite a cause que leau rentrai vite*
2.4.1 Student 15: *moi je crois que la boule compressée n'a pas coulée parce que l'eau rentrait dedans mais parce qu'il n'y avait pas d'air dedans et qu'elle était plus lourde que la place qu'elle occupait.*
2.5 Students 15, 16, 17 and 18: *Nous croyons que la boule lâche va flotter car elle a de l'air à l'intérieur.Par contre, la boule serrée va couler car elle n'a pas d'air à l'intérieur d'elle.Nous croyons aussi que la boule lâche pourrais flotter car elle est aussi lourde que la place qu'elle occupe sur l'eau.La boule serrée pourrait couler car elle est plus lourde que l'espace qu'elle occupe.*
2.5.1 Students 15, 16, 17 and 18: *Après l'expérience, nous avons remarqué que nos prédictions étaient juste.*

Note 2.1 contains Student 8's prediction, followed by her observations indicating that she revised her note following the experiment. No explanation is given however to the phenomena observed. By adding "we were right" in her note, this student expresses a natural concern to "get the right answer" rather than be able to explain it. This is very common unless the classroom culture is intentionally oriented toward learning goals rather than performance goals

[23] Although notes 2.1 through 2.5 were created sequentially, the database indicates that notes 2.1, 2.2, 2.3, 2.4 were all modified on March 15 while the other notes were dated February 27 or March 1st. This leads us to believe that the students were indeed asked to go back to their original idea and revise their notes but instead of leaving their initial ideas in the note, some of them chose to write instead the 'correct answer' i.e., their observations from the experiment. Notes 2.1 and 2.2 report their observations while the remaining notes offer explanations too.

(Bereiter & Scardamalia, 1989; Bransford et al., 2000; Brown, 1997; among others). Note 2.2 is similar in nature in the sense that Student 9 reports that they "were wrong" and states his observations, but again, without providing any explanation. In these two notes Teacher C3a added annotations asking them to further explain their theories, predictions and observations. In doing so, she reminded the students directly in the online environment that they were expected to explain their ideas. In note 2.3, Student 10 explains that the compact ball sank because there was no air in it compared to the looser one in which there was.

The next two notes generated one elaboration each bringing the discussion a little further. In note 2.4, Students 11, 12, 13 and 14 believe like Student 10 that the compact ball sank because it did not contain any air. They add that it was flat and that the water "came in fast". Here too, Teacher C3a asked them to explain further what they meant by saying that "water came in fast" in an annotation.

In note 2.4.1, Student 15 disagrees with this explanation. She thinks that the compact ball did not sink because water "came in" it but because there was no air in it. What she adds further is even more interesting. She says that the compact ball was "heavier than the space it occupied."

We claim that this idea of weight and space is a clear, if incomplete, reference to the concept of density (or *masse volumique*) as the relationship between a given mass ("heavier") occupying a given volume ("space") and its buoyancy. Although the student uses layperson terms instead of the more scientific term of "density", she is referring to the same idea. In Roschelle's terms (1992), the student uses this metaphor in relation to an intermediate conception – or deep-featured situation – of buoyancy, and that the situation is essentially correct although stated in layperson terms. Unfortunately, the threads stops at this point but the next note, co-written by the same author two weeks later offers some further insight on this intermediate conception.

In note 2.5, Students 15, 16, 17 and 18 also believe the looser ball will float because it contains air, while the compact ball will sink because it does not. They also believe that the looser ball could float because "it is as *heavy as the place* it occupies on water." The compact ball could sink because it "*is heavier than the space it occupies.*" In this statement, the students suggest the same explanation of buoyancy as in the previous note, i.e., that an object denser than water – or too heavy for the space it occupies – should sink. But the first statement about the looser ball mentions an object *as heavy as the space it occupies*. As such, it appears that the students are beginning to engage in an iterative cycle displaying, confirming and repairing their conception of the deep-featured situation in relation to their own metaphors. Note 2.5 being dated two weeks prior to note 2.4, it is possible that note 2.4 contains a later conception of density, but they are both using the same terms that we could interpret as a first sign of convergence. Note 2.5.1 does not add anything new as the four students report that their predictions were "right."

Although there was no further elaboration on this idea of an object being heavier than the space it occupies, the post-test answers of these four students are quite interesting and show for each one some departure from their initial conception as displayed in their pre-test. Student 16 now uses the same intermediate conception displayed in the note to explain that in order to float, an object's weight has to be equal to the space it occupies. However, Student 16 was not able to answer question 5 and explain the relationship between the relative density of an object and that of the liquid in which it is submerged and buoyancy, showing that his understanding – or system of knowledge elements – of buoyancy was not yet entirely coherent. Student 17 also mentioned in his post-test that "objects sink or float because whether they are heavy or light and also because *either they take more space then they occupy or less space then they occupy.*" Here too, we can see that the idea of space occupied by the object is understood as having an effect on buoyancy but the student's conception is still parceled out because he fails to mention the object's mass in relationship to its volume. We argue that this is further evidence of the students' having partly integrated this intermediate conception of buoyancy but not having been able to integrate all of the *p*-prims necessary to form a complete and coherent knowledge system of buoyancy.

Student 18's answers are puzzling. Indeed, in most of her answers, she states that floating objects are simply made of materials that float and vice versa. However, her explanation of buoyancy is complete and coherent in her last answer: "if the liquid is denser than the object, the object floats, but if the liquid is less dense than the object, the object sinks." We might wonder how a student could be able to answer at a higher level of abstraction a question that she could not explain at a lower level of abstraction. We argue that this suggests the presence of a system of knowledge about buoyancy that includes complex and well-organized abstract elements of knowledge about buoyancy. It also includes elements of knowledge from prior conceptions that still require gradual change to successfully reflect a scientifically-accurate understanding of this phenomenon.

Finally, Student 15 post-test answers offer two explanations, first that floating objects contain air (one part of her initial conception that was stated in the pre test as well in note 2.4.1) but also mentions the idea that it should be "*smaller than the space it occupies*." This indicates that her conception of buoyancy has not progressed beyond that displayed in the notes. We could even say that it has somehow regressed because she no longer refers to the mass of the object ("heavy") but only to its size ("smaller"). This too provides further evidence that the intermediate conception is not yet a solid and complete system of knowledge elements that can successfully help her understand buoyancy but that it is in fact incomplete and still quite fragile.

Discussing Buoyancy - Excerpt 4[24]

This last discussion thread addresses the driving question of this inquiry i.e., how to make an egg float. This group of students proposes two different ways to make the egg float and discuss each idea.

7.6 Students 19 and 20:
notre équipe est diviser en deux nous nous croillon que l'oeuf va flotter dans l'eaux saler et l'autre moitier croix que l'oeuf va flotter dans de la mélasse.l'oeuf va fotter pcq il va il va etre surparter par l eau salée.l autre équipe pense que sa va fotter pcq la mélasse est épaise.

7.6.1 Students 19 and 20:
Mes observations après l'expérience nous avons vues que l'oeuf des de l'eau salé (unpeu moin que une demi tasse de sel et 2 tasse d eau) pcq dans la mer ont flotte et c'est de l'eau salée. ont avons réussi !!!!!!!!!

7.6.1.1 Teacher:
Avez-vous vérifié pourquoi on flotte plus facilement dans de l'eau salée? Allez sur wikipedia et cherchez mer morte....

7.6.2 Students 21 and 22:
l'oeuf flotte parce que la mélasse est plus dense que l'oeuf

[24] The English translation is available in Appendix J.

In note 7.6 Students 19 and 20 explain that their team is divided in two: they believe that an egg should float in saline water and the other half of the team believes it will float in molasses. The egg will float in saline water because the water will support the egg. The others believe the egg will float because the molasses is thick. In this note, the teacher added a series of questions in an annotation: How will you verify your prediction? What motivates your choice? Why should the egg float? Is one hypothesis better than the other? This series of questions shows what form online teacher mediation can take. In this case, the teacher reinforces the need for the students to further explain and argument their point to complete their note. The teacher chose to use annotations but she could have contributed a note too.

In note 7.6.1 Students 19 and 20 note their observations. They say that the egg did float in saline water and explain it by saying that the Dead Sea is saline and we float in it. They believe their experiment was a success. The teacher asks in note 7.6.1.1 if they verified why we float more easily in saline water and suggests they look up Dead Sea on Wikipedia. Unfortunately the discussion thread ended on this note.

In note 7.6.2, Students 21 and 22 who are experimenting with molasses, explain that the egg floats because molasses is denser than the egg. This note received three student annotations all asking for further explanation of their idea. This is an illustration of how students themselves can motivate their peers to further explain their ideas. It shows ownership of the quality of the discussion on their part and this is to be encouraged. However, here too, the discussion thread ended.

From the students' pre- and post-test answers, we can see that some of them did show evidence of conceptual change while others did not. Student 19 initially believed that buoyancy is related to the object's weight and she still believes it is the case in her posttest. Student 21 and 22's conceptions of buoyancy seem to have changed. While Student 21 initially believed that buoyancy was related to an object's weight, his post-test answers mention density. In question 3, he explains that "the marble sinks because it is *too dense for the space it occupies*" again using the intermediate conception of density we have discussed before. However, his conception of buoyancy was not complete or coherent enough to enable him to answer question 5. Student 22 on the other hand, believed that buoyancy had to do with the presence of air in objects in his pre-test. However, in his post-test he answered to question 5 that "liquid makes objects float if it is dense and objects sink when they are dense." This answer reflects an almost complete conceptualization of the phenomenon since it mentions the density of the liquid *and* the density of the object. It is not yet complete however since it does not yet reflect the relationship between the two. In this case too, however incomplete his system of knowledge elements was, it enabled him to successfully understand the phenomenon of buoyancy.

Discussion of the Results

The research question addressed in this last part of the results was: Can this particular collaborative problem-solving context lead to conceptual change? If so, what are the characteristics of students' conceptual change process in this context?

The results presented above have provided evidence that this collaborative problem-solving context could lead to conceptual change providing sufficient teacher mediation to that effect. Furthermore, a micro-level analysis of the students' ideas about buoyancy as expressed in the Knowledge Forum notes as well as in their pre- and post-test answers has provided some insight into the characteristics of student conceptual change in this context.

First, the micro-level analysis of the students' ideas about buoyancy has shown that, for some students, their prior understanding of this phenomenon was not changed in the process of this activity but, for others, it was changed to different degrees. As depicted by Smith and colleagues' knowledge system framework (1993) some students' representations of buoyancy form coherent knowledge systems that are more efficient and reliable than others', but all of them seem to have been gradually constructed from their prior knowledge.

The analysis of the students' ideas has also given us some insight about their conceptual change process. Unfortunately, the observed context could only provide us with pieces of the collaborative conversation and not the entire episodes as a regular conversational analysis of a face-to-face discussion between students could have. While some excerpts did provide us with some hints of Roschelle's (1992) proposed convergent conceptual change process, such as the construction of deep-featured situations at an intermediate level of abstraction (or intermediate conceptions) of buoyancy, the use of metaphors in relations to those intermediate conceptions and what we could interpret as tentative cycles of displaying, confirming and repairing situated actions, we have not collected the evidence necessary to illustrate a complete convergent conceptual change process as proposed by Roschelle. Many factors can explain this.

First, an asynchronous collaborative conversation is not a synchronous conversation: delays between utterances are quite different than that of a natural conversation. Although the need to write their ideas involves more reflection on the part of the students than would an oral conversation, generating all the while traces of the thinking process, it lacks the flow of a synchronous conversation. A conversational analysis of this new form of conversation thus generates results that are slightly different from traditional oral discourse. What is more, due to the combination of classroom and online discussions, many conversational acts could not be collected. In some instances, inferences about these missed acts had to be made.

Second, the possibility of elaborating on others' note does not automatically lead to it. In fact, the online conversation can easily stop at any point in time. There often needs to be specific expectations of the teachers to keep the online collaborative conversation going. Without such expectations, online conversation can easily consist of single, un-elaborated notes. As stated before, students do not naturally read and elaborate on each other's notes but rather prefer to answer the teacher's notes. They are able to comment on each other's ideas but do not necessarily take the time to see if their contribution is different from someone else's unless specifically asked to do so. In order to go beyond this natural tendency, students and teachers need to develop and agree on "asynchronous collaborative practices" that will enable them to use the tool to its fullest potential. The development of new classroom practices such as this take conscious efforts on the part of the teachers as well as classroom time. Such results have been reported before (Allaire, Beaudoin, Breuleux, Hamel, Inchauspé, Laferrière, & Turcotte, 2006; Hakkarainen, 2004; Laferrière, Breuleux, & Inchauspé, 2004; Riel & Levin, 1990; among others).

This could explain the difficulty to engage in complete convergent conceptual change processes as observed here and in the other online activities carried out in the participating sites. The possibility to engage in iterative cycles of displaying, confirming and repairing students' situated action that would lead students to develop a common understanding is provided by the tool but requires quite specific teacher mediation. Students must be expected to do it and sufficient successful online collaborative opportunities are needed. This requires teachers to understand why they should invest time into this, to know how to do it and what to look for in the students' discourse once they are effectively engaged in a convergent process. Roschelle himself mentioned that the students in his study "intentionally employed their ability to coordinate conversational acts that display, monitor, and repair knowledge so as to bring their understanding into convergence" (1992, p.266). We suggest that this intentional learning process has to be modeled in order for students to succeed in making the most out of their collaborative learning process.

In the particular collaborative learning context studied here, other factors were also at play. Indeed, the utmost intention of the teachers was to get their students to work with other students in the Knowledge Forum on a science problem. Logistical issues such as coordination between classrooms at different times during the inquiry, fixing technical problems, organizing classroom periods around the accessibility of computers, helping students work with the tool, and many others have made it difficult for students to write as much as 5 notes in each activity. Keeping this in mind, it is not surprising that there were not as many traces of convergent conceptual change in the online discussion as we had first hoped. The fact that students' prior conceptions were shared online was already a significant departure from traditional science instruction in these classrooms, as discussed in the interviews.

In sum, the present study generated the results needed to answer the third and last research question of this doctoral dissertation.

CHAPTER 5 – DISCUSSION

This chapter discusses the contribution to knowledge, the implications of this study in relation to student learning and teacher professional development and suggests possible future research extensions building on the Remote Networked Schools initiative. It also presents the limitations of this study.

Contribution to Knowledge

This study explored computer-supported collaborative inquiry in the context of small rural schools developing new classroom practices using the Internet to enrich their learning environments. Taking advantage of the fact that the participants were already engaged in innovation efforts as Remote Networked Schools, and having some idea of the types of activities that they had conducted online previously, the ambitious goal of this dissertation study was to push things further by focussing more closely on science instruction in such a context. Indeed, most of the activities conducted until then using the Knowledge Forum in these classrooms had consisted primarily of "peripheral" activities (e.g., preparing for Halloween and Christmas activities) or aimed at developing competencies such as "communicating with others" and "using technology tools" but few had worked on discipline-related objectives such as science problems. Hence, we wanted students to work on specific learning goals from the 3rd cycle elementary science curriculum. What is more, we not only aimed at conducting science activities collaboratively between schools, but we also wanted to focus on developing the students' understanding and practical use of an inquiry process and promote deeper understanding of science phenomena. Finally, we wondered if such context would allow us to gather evidence of conceptual change and if so, what would be the characteristics of conceptual change in this particular context.

From the outset, we were well aware that these goals were quite ambitious. However as this was a design experiment, we knew that we would probably need to adapt our initial research design to each situation. While ultimately hoping to promote, document and study conceptual change in this innovative learning context, we were foremost interested in conducting this study in an authentic classroom context, with its authentic characteristics and challenges. We aimed to study how typical teachers would integrate the proposed inquiry process in their classrooms and we acted towards that end when supporting them in their practice, adjusting to their needs as they expressed them and providing just-in-time help whether on the use of the tool or on pedagogical strategies. Indeed, we believed (as we still do) that there was no sense in creating an artificial learning context to generate outstanding data if there was no chance for these new practices to survive this study. To this end, a first research design was presented to the teachers that involved using the inquiry process in the Knowledge Forum to support their students' problem-solving processes but the choice of the activities and how they were conducted in the classroom remained the teachers' responsibility. The researcher acted as a resource person as needs emerged and shared with the teachers her observations throughout the process. Reflection on teaching practices and student learning were thus continuously discussed during the year as both teachers and researcher developed their own understanding and knowledge about what was happening in the different sites. In many senses, it was a year-long professional development opportunity for everyone actively involved.

Another particular feature of this study is the fact that it was conducted over the course of a single school year. Research has shown that educational innovations usually take much longer to be implemented (Becker & Riel, 2000; Blumenfeld, Fishman, Krajcik, & Marx, 2000; Cuban, 2001; Fullan, 2001; Seidel & Perez, 1994; among others). In this study however, we framed the innovation within the context of one full school year. While we did benefit from the teachers' previous experience in the RNS, we believe that we were able to capture the reality of classroom life with all that it entails. The fact that the data collection spanned over a whole school year, for us, is also consistent with having worked in an authentic classroom context.

Finally, we acknowledge the fact that it was risky to transfer to an asynchronous context a model of conceptual change that relied on conversational analysis but we believe that this study has managed to prove that it was indeed possible to a certain extent.

Overall then, we believe that this study has contributed to the generation of new knowledge about how we can study science learning and conceptual change when students from different schools use computers and digital scaffold supports to support their collaborative inquiry. While we might not have been able to observe evidence of conceptual change processes of great magnitude, we have developed new ways to explore and demonstrate how to examine student conceptual change in collaborative inquiry from the analysis of artifacts created through the use of an asychronous tool such as Knowledge Forum.

This study has also generated new knowledge about innovative teaching practices and how they are developed and implemented in authentic classroom contexts.The study has therefore succeeded in advancing our knowledge of the problem space and the moves that are likely to lead to a greater understanding of learning and teaching in these particular contexts.

Implications for Student Learning

Student Prior Knowledge

The results obtained in this study provide further evidence for the crucial role of student prior knowledge to construct new representations that is, to learn about new phenomena. As argued by diSessa and his colleagues (diSessa, 1993; Smith, diSessa, & Roschelle, 1993), a complex system of knowledge elements that gradually evolves from naïve to more expert-like conceptions can better explain how knowledge about gravity and air resistance may help students to understand, at least partly, the buoyancy of a raft. The results obtained confirm that this "knowledge-in-pieces" model better accounts for student learning than would other models of conceptual change (Chi, 2005; Chi et al., 1994; Posner et al., 1982; Strike & Posner, 1992; Vosniadou, 1994, 1999). Indeed, these results confirm that while naïve conceptions have often been dismissed in much of the conceptual change literature, they can be useful and effective depending on the context and thus should not be overlooked in research as well as in classroom science instruction.

As revealed in the teachers' interviews, students expressed their prior knowledge more than they had before this study. Indeed, time was specifically taken for students to propose theories to explain certain scientific phenomena and related predictions about what would be later observed in the experiment. According to their teachers, time to reflect on the phenomenon before going ahead with the experiment itself was rarely provided in these classrooms prior to this study. Science experiments were considered fun and active and thus enough to ensure student learning. In the course of this study however, students were given extra time to reflect and express their ideas as well as consider those of others. This provided rich opportunities for teachers to address their students' understanding of the topic at hand or lack thereof. Moreover, because their ideas were shared online, artifacts were created whereas no traces of their deliberations had existed before. These artifacts provided additional opportunities to reflect on prior knowledge after the experiments were conducted. Unfortunately, students were not systematically asked to go back to their initial theories and relate them to what they had just observed, as suggested by the researcher and supported by Palincsar and Herrenkohl's (2002) study. We firmly believe that if that had been the case, there would have been even more traces of conceptual change in the notes produced as well as a deeper understanding of the phenomena explored that would have resulted in higher post-test scores.

Regarding Roschelle's (1992) model of convergent conceptual change, we also believe the particular context of this study could have generated additional opportunities for iterative cycles of displaying, confirming and repairing situated actions in relation to an intermediate conception to the point of generating convergence if specific teacher actions to that effect had been taken. Indeed, the students displayed their understanding of buoyancy but the partial iterative cycles observed necessitated direct teacher mediation to be completed. Indeed, students would have needed to be asked to revise their notes until they had come to a common understanding for buoyancy. Knowing how difficult it was to successfully access the computers once or twice in the activity, whether because of technical or logistical constraints, it is easy to understand why this opportunity to deepen their understanding was lost.

We believe that an iterative cycle such as the one described by Roschelle's model (1992) could take place online as well as it could take place in the classroom in front of the computer, for example, but for this to happen, convergence would have to be *expected* of the students. Even though this study did not provide sufficient evidence to confirm the existence of Roschelle's model of convergent conceptual change in the present learning context, we firmly believe that some instances of the steps of the convergent conceptual process discussed in this study confirm its importance as the most complete model of conceptual change that exists to date.

Explanation-Based Activities to Promote Deeper Understanding

Much as it is the case in classroom settings without computers, explanation-based activities in the context of computer-supported collaborative learning are key to promote student critical thinking and deeper understanding (APA, 1993; Barak, Ben-Chaim, & Zoller, 2007; Bransford, et al., 2000; Bruer, 1993; Coleman, 1998; Hatano & Inagaki, 1987). In this study, students were regularly encouraged to provide explanations about the phenomenon resulting in generally high-level ideas according to Hakkarainen's level of explanation scale (2003a). While teachers were not always convinced of their students' capacity to generate explanations, the results show that the students were in fact contributing more explanations than facts to the discussion. Indeed, teachers in this study were often amazed by the kind of answers their students generated when given the opportunity. On occasions, they had underestimated their students' prior knowledge about a topic and were taken aback by what they heard or read online. While this may be a little disconcerting at first, teachers should make the most out of these cases and not hesitate to go beyond what is stated in the curriculum. When students are deeply engaged in inquiry, they will not hesitate to go overboard and gather advanced information and resources (Scardamalia & Bereiter, 1999). In such cases, teachers could assign the responsibility of this part of the project to the student. In doing so, the student's engagement will be rewarded, agency will be developed and a culture of learning resembling that of a community of learners could begin to emerge (Bielaczyc & Collins, 1999; Brown, 1997; Brown & Campione, 1994).

Scaffold Supports and Inquiry

The relevance of engaging students in inquiry to help them learn science has long been recognized (AAAS, 1993; APA, 1993; Bransford, et al., 2000; NRC, 1996). Using an approach to scientific inquiry such as the one proposed by Palincsar and Herrenkohl (2002) engages students of all ages in an authentic inquiry practice, a sort of cognitive apprenticeship in science (Barab & Hay, 2001; Collins, Brown, & Newman, 1989; Roth & Bowen, 1995) and bring students to understand the fundamental nature of scientific activity through legitimate peripheral participation (Lave & Wenger, 1991): answering a question about the world through rigorous observations, experiments and constant reflection, explanations and revisions about what was expected and what was actually observed. While science is often perceived as "conducting experiments", it is important to put more emphasis on the reflection needed *before* and *after* the experiments are carried out, even if it appears more difficult and less exciting. Without it, we know that teachers run a high risk of wasting their and their students' time (see Minstrell, 2001).

Research has shown the importance of scaffolding students' inquiry process to promote learning (Brown, 1997; Brown & Campione, 1994; Herrenkohl et al., 1999; Krajcik et al., 1998; McNeill, Lizotte, Krajcik, & Marx, 2006; Pea, 2004; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan et al., 2004; White, 1993;White et al., 1999) and has stressed the importance of helping students distinguish theories from predictions through consecutive discussions. The results of this study have also shown that, when used with sufficient teacher mediation and modeling, using scaffold supports to model the inquiry process can help students to engage in authentic inquiry processes and develop a deeper, practical understanding of what science activity consists of as well as help them develop metacognitive skills. However, for the different steps to operate effectively as scaffolds in the Knowledge Forum, or as prompts in other learning contexts, they must be modeled adequately by the teachers. If none of the educators specifically model their coherent use, they will not in and of themselves support the students' inquiry process. For this reason, we suggest that a future study should include teachers using and discussing the scaffolds, perhaps even conducting amongst themselves a genuine scientific inquiry as an object of professional development.

Implications for Professional Development

Supporting the Collaborative Conversation

One clear implication of this study is the need to help teachers to better support the collaborative conversation online as well as in the classroom (Barron, 2000; Palincsar, 1998; Herrenkohl, 2006). Classroom discourse research (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005; Cazden, 2001) has discussed the overwhelming presence of the I-R-E sequence in classroom discourse and has illustrated the importance of helping teachers foster richer participation structures and student-student interactions. In the case of collaborative contexts such as this one, when partners are not in the same physical space, collaboration does not come naturally, but needs to be modeled even further. Indeed, while the tools themselves provide the opportunities needed for collaboration to take place, it is not enough for collaborative learning to occur. As we have observed in the micro-analyses of the excerpts (Chapter 4, pp. 136-151), convergence — the crux of collaborative learning according to Roschelle (1992) — does not happen automatically either, but requires intentional learning (Bereiter & Scardamalia, 1989). In order for it to happen, more specific directives to that effect should ideally have been established in the sites studied. For example, students working in teams could have been declared responsible for the entire inquiry process and expected to explain the results of their experiments to the rest of their group, thus generating a *need* for convergence between the group members. This was part of Palincsar and Herrenkohl's (2002) study of cognitive tools for intellectual roles. Unfortunately, it was not put into practice sufficiently in this study even though many suggestions to that effect were made to the teachers throughout the year.

We believe that coordinating the students' work on the computers with the other class and adapting the didactic materials to their particular context and "learning sequence" demanded a lot of time and effort on the part of the teachers. Judging from many conversations with them, it was clear that organizing their classroom time around the inquiry activity was more difficult than we had anticipated. Starting the activity, helping students develop their theories and predictions and creating schedules for them to post them on the Knowledge Forum was a real challenge, especially in classrooms where the student to computer ratio was high. Once the students had completed the hands-on experiment and posted their results, their motivation to go back to their initial notes was very low and a lot of time had already been devoted to the activity. We believe this could explain why the last part of the inquiry process, i.e., relating observations to initial theories and predictions, was generally overlooked. In retrospect however, most of the teachers recognized that this part of the process had been neglected and they mentioned that they needed to work on it in the future.

We believe that teacher education programs should come to include learning activities aimed at helping future teachers to foster conversations with their students on scientific concepts, especially about their naïve conceptions (Echevarria, 2003; Minstrell, 2001). Judging from our observations on site, from the didactic materials used by the teachers as well as from discussions with the teachers throughout this study, it appears that although the science materials often include common student misconceptions and ideas on how to start the conversation for each activity (e.g., Thouin, 1999), the students' conceptions are rarely used as starting points to learning and the conversations are often found difficult to engage. More often than not, the concepts are "taught" rather than discussed collaboratively and the resulting student understanding tends to be quite disappointing. Professional development opportunities to that effect would also be useful in helping teachers become more comfortable with the science program when they are not, and thus become more open to engage their students in authentic inquiries and genuine conversations that better foster science learning. We argue that helping teachers identify student prior knowledge and gradually refine their knowledge systems toward a scientifically-accurate understanding of the phenomena explored, with and without the support of digital tools, should be given additional attention in Quebec teacher education programs and professional development activities.

Until such changes are integrated in the education programs however, researchers interested in conducting research of this nature would be well advised to take additional time to choose the teachers they want to work with, perhaps by observing a science lesson from the outset and exploring teachers' ideas about inquiry (see Windschitl, 2003). In the present study, the initial objectives were quite ambitious but the overall intention was always to work with authentic classrooms, students and teachers, in authentic innovative contexts, with all that it entails. Even if the proposed "intervention" was articulated around Herrenkohl et al.'s work (1999), we were very much aware of the complexity of the context in which it was to take place. Although the chosen participating sites showed the most promise in terms of innovative practive and conditions of innovation (see Chapter 2, pp. 61-62), we knew from the outset that many other factors would come into play, notably the teachers' epistemology (Hakkarainen et al., 2002; Windschitl, 2003), their level of comfort with teaching science and with technology, their ability to coordinate collaborative activities across schools, technical and logistical difficulties as well as all other ordinary school-life events such as maternity-leave, personel turn-over and work overload. In light of such complexity, we find the results of this study very satisfying. Future work explicitly oriented towards detailing more complex accounts of convergent conceptual change in computer-supported collaborative inquiry should be conducted in settings where these collaborative practices are already well institutionalized.

Scaffolding the Inquiry Process

Another difficulty identified by the teachers is how to efficiently scaffold students in their inquiry process. The results from Windschitl (2003) are consistent with the situation here in that most of the teachers in this study had never carried out an actual scientific inquiry on their own. In consequence, it was difficult for them to integrate inquiry in their classroom practice. While most teachers know about the "scientific approach" as a series of steps to follow in a scientific inquiry, truly experiencing the process remains quite abstract: the need to go back to the initial questions and theories once the experiments have been carried out is not a part of their usual science teaching practice. This translated, among other things, into a general difficulty in figuring out a coherent sequence of activities between classroom and online work. It is our belief that teacher education and professional development programs should include genuine scientific inquiries for student-teachers and in-service teachers when they do not already.

Until they do, teachers and researchers interested in conducting this type of research may benefit from engaging in reflective practice (Schön, 1983) on their own experience of inquiry before starting a new research project. This could help each actor to better orient its actions. For example, teachers may want to engage in an online conversation about inquiry in their classrooms with other colleagues interested in further developing their own understanding of this process. While this idea was presented to the participants of this study but was not followed through, we still believe it could be a way to share and explore epistemologies about science and work around those ideas towards a greater understanding of inquiry and scientific activity in general. Online professional development opportunities have not yet been integrated to in-service teachers' regular professional practice but holds true potential, especially in remote settings such as RNS where professional isolation is the norm rather than the exception. Communities of practice of this nature would not only help teachers develop their understanding of an inquiry process and potentially improve science instruction, but would also provide researchers with opportunities to fully take part in this professional development while generating additional knowledge about science education.

Optimizing Time Allotted to Science

Teachers in this study have often mentioned the opportunity for their students to be in contact with new ideas as their major source of excitement about the RNS initiative. However positive, this web-enabled contact with new ideas should not be the end target here. Indeed, it is what can be learned from sharing ideas that should stay the focus of interest. Lost in all the other logistical issues that were unfortunately at play (coordination issues, technical difficulties, learning curve of the tools used, classroom management issues, etc.), the learning goals took too often the backseat. Blumenfeld and colleagues (2000) have previously discussed the difficulties associated with such innovative projects. With so little time devoted to science during the school year, it was quite disturbing to hear one teacher acknowledge matter-of-factly that her students could not explain the few scientific concepts around which they spent as much as a third of the total time allowed for science. In this particular case, the teacher appeared surprised but not otherwise bothered. Knowing that the general feeling among the six participating teachers was that the Quebec science curriculum is 'simply impossible to cover' this fact alone would not be as alarming. We could simply dismiss the activity has having failed, which can happen once in awhile. However, in the majority of these classrooms, the three to four activities discussed in this study were the only science activities conducted during the year. Making sure the students have understood the few concepts covered in each one should be at the very least a prime concern. Unfortunately, it did not appear to be the case. We claim that this should be directly addressed in the current Quebec teacher education programs as well as in professional development activities. This is a clear case of the classic dilemma of coverage versus deep understanding in the teaching for understanding literature (APA, 1993; Bransford et al., 2000; Gardner & Boix-Mansilla, 1994, among others).

Challenges of Computer-Supported Collaborative Learning in Science

Coordination and Planning of Activities

A constant challenge with computer-supported collaborative learning activities in the context such as the one studied here had to do with coordination and planning. Indeed, a lot of teachers' time and energy was spent in organizing their students' online work. A first challenge experienced by the teachers was to identify when to get students to work on the Knowledge Forum as they explored the didactic materials they were using. It was not always clear for them how to do this and the researcher often helped them to identify potential sequences of events between classroom and online discourse around the experiments per se. Once the general sequence was planned, the teachers of the collaborating groups had to further coordinate day-to-day science activities in order to minimize delays for everyone. For example, a group of students would first put up their theories. Then the other group was to put theirs and elaborate on the first group's notes in a relatively short period of time so that the first group would be able to go on with the experiment but only after their partners had shared their theories and predictions. Similarly, once the experiment had been conducted in one group, the second group had to do it also relatively soon so that they would not 'spoil the surprise' by sharing their observations online. This back and forth movement between classroom and online work to be coordinated with a second group with its own time constraints proved to be quite a challenge, and a great source of frustration which was previously addressed in Riel and Levin (1990). Indeed, when one group was not able to respond to their partner group in short enough delays, it often caused frustration among students eager to continue their work but also among teachers ready to move on. This study has revealed that one effective way to ensure adequate momentum for all is for collaborating teachers to communicate everyday and science inquiries to be organized over a short period of time, over a couple of weeks for example. Also, when students were given time to work on their notes and to talk to each other via desktop videoconferencing almost everyday, motivation stayed high and satisfaction with the activity was shared by students as well as adults.

Another source of concern relative to problems of coordination between groups has to do with asymmetrical engagement, the impact of which has also been discussed by Riel and Levin (1990). Indeed, we have seen in this study that very small groups teamed with normal-size groups experienced many challenges in terms of participation rates. This experience has shown that although the smaller group was able to contribute at least as much as the greater group, the imbalance in participation was a constant source of frustration for the smaller group, eager to collaborate with new students. In the future, we believe that this particular classroom, or others like this one, would be better served if they could find a smaller group to work with, even if it had to be from a different site, especially if issues of asymmetrical engagement cannot be otherwise addressed. Aside from their high level of engagement, we believe that their particular status as a very small group gave them more flexibility to organize their classroom practice and that trying to work with a regular-size classroom with very different constraints was both impractical and unsatisfactory for the two groups. As for the other collaborating groups, even when they were of similar sizes, this study has shown that asymmetrical engagement in bigger groups can also be a source of frustration and should be adjusted as quickly as possible when noticed (Riel & Levin, 1990).

Supporting a Computer-Mediated Conversation

Aside from the usual challenges associated with supporting a collaborative conversation such as discussed by Palincsar (1998) which still prevail, the case of computer-supported collaborative conversation presents some additional difficulties. For one, there is a need to *plan* the conversation a step further. For example, teachers must first decide which question should launch the conversation, making sure the question is as authentic as possible to engage students, and formulating it in a way that is open- rather than closed-ended. As we have seen, if the question is explanation-seeking in nature rather than fact-seeking, it tends to generate richer contributions and thus it is encouraged. But formulating the question, although an important task in itself, does not warrant cooperative learning, let alone collaborative learning. Indeed, there is also a need to plan ahead the types of answers teachers expect from students, not in terms of their ideas, but of their intentions. For example, teachers may decide to ask students to generate one theory or one prediction to answer the question, or to complete one of their peers' ideas. Furthermore, teachers may insist that each note bring something new to the discussion, thus requiring that students read each other's notes before contributing their own. As we have discussed earlier, students do not naturally read or elaborate on each other's notes unless they are specifically asked to do so. In time they will, but as they begin to learn new collaborative practices, these simple directives will help them to adopt collaborative practices that should lead to richer exchanges online.

Authentic Audience and Student Motivation

Although using an synchronous tool such as Knowledge Forum requires more efforts from elementary school students who are not all comfortable in their writing practice, engaging them in important, discipline-based learning activities through writing such as was the case in this study provides in turn authentic writing opportunities that enrich their learning experience. The same could be said of reading. Indeed, when surveyed on their motivation to read and write, most students scored very low but when questioned about their work online, a lot of the same students told teachers and members of the research team that they did not consider their work on the computers as reading or writing (C. Hamel, personal communication). This comment revealed a surprisingly strong difference in students' perception of a "classroom reading and writing task" and reading some other student's note and elaborating on it. While we already knew that students were greatly motivated to exchange notes with other students, this perception had deep resonance in our work. Indeed, teachers should be encouraged to develop authentic writing and reading tasks just like the ones conducted in this study i.e., on authentic and important parts of the curriculum such as science but also history, math and language arts, and not only on peripheral activities, which is often too the case when trying something new. The other classroom as a real audience is a powerful motivator and should be used as such to foster important student learning.

Conditions of Innovation

If other computer-supported collaborative learning initiatives like Remote Networked Schools were to be launched elsewhere, whether they focused on science education or not, we could not stress enough the importance of ensuring Ely's necessary conditions to implement educational technology (Ely, 1999; Ensminger, Surry, Porter, & Wright, 2004; Turcotte & Hamel, 2008). Indeed, we conducted this particular study in classrooms and schools sometimes as much as three years into the RNS project, and even if the classrooms picked to participate showed the most promise in terms of the presence of conditions of innovation, problems with technology and leadership were recurrent in all of the sites. These problems had tremendous impact on the teachers' workload and unfortunately, made it easier for them to loose sight of the learning goals pursued. When week after week, teachers spent time to organize collaborating activities with a partner but still had to revert to the telephone because the Internet connection was still not working properly, when lab computers had so many security codes it took forever to get the students to work, and when the school laptop did not even have an accessible hard drive to save files, it made it very difficult for teachers to focus on teaching and learning. It is a wonder why none of the teachers gave up and simply reverted to their usual – and reliable – classroom practices. If we want teachers to integrate the use of Internet and computers in their classroom practice, school technology infrastructures and services must be organized to meet their needs and not the other way around. In many of these schools, this was unfortunately not the case.

Another condition of innovation that is crucial in studies such as this one is leadership. Indeed, when teachers invest time and effort into bringing together two classrooms using networked-computers, school management should stand behind those efforts and recognize the added work. More than half of the teachers in this study did not feel supported or recognized for their innovation efforts. Without this recognition, it would not be surprising to see computer-supported collaborative activities be abandoned in the future, despite their potential for student learning. Fortunately, RNS activities over the last few months have shown that the institutionalization of RNS practices is well underway.

Finally, in order to help teachers to develop the knowledge and skills required to effectively engage their students in computer-supported collaborative learning, time and resources must be invested in their professional development. However, we believe that occasional training on one tool or the other is not enough. Indeed, we have been told many times that the ongoing support provided by the RNS research and intervention team, through email and desktop videoconferencing among other things, was tremendously helpful in getting the teachers comfortable with the tools. They also appreciated the opportunity to discuss the pedagogical intentions behind the activities conducted in this particular study as well as in others conducted in the context of the RNS initiative. Changing classroom practices to include the effective use of networked computers requires much more than periodical training sessions. Constant and quick access to resource people during actual classroom hours has shown to be reassuring for teachers and efficient in helping them develop new classroom practices at their own pace thus better meeting their professional needs.

Limitations of the Study

A first limitation of the study is related to its external validity. The participating classrooms of this study were homogeneous in terms of socioeconomic status (SES) (see Table 1). Indeed, four out of the six classrooms were from low SES while the other two were from medium and high SES. Chosen as Remote Networked Schools partly for that reason, these schools thus represent only part of the elementary school population in Quebec.

Also, the schools studied are all located in small rural areas, usually far from cities or even larger rural settings. They also consist of small schools in terms of the number of students and teachers. Therefore, generalizability of the results obtained to bigger, urban and suburban schools might be risky to some extent.

Another particular feature of this study is the presence of only one male teacher in the sample. While it would have been interesting to have three teachers of both genders, this ratio is consistent with Quebec elementary schools in general. However, this teacher was one of the most comfortable with science teaching as with technology, the result of which may have introduced a confounding factor in these results.

Moreover, all of the participating teachers in this study were willing participants. They all agreed to conduct science activities in the Knowledge Forum in the context of this doctoral dissertation. While school management acknowledged their participation as a sign of commitment to the RNS initiative and while it did provide them with individualized technical and pedagogical support, their participation is a sign of motivation and engagement to their teaching practice. In this sense, the sample has included participants generally interested in using the proposed knowledge building tool to support their student learning. Random attribution of RNS classrooms would probably have generated different results.

Another limitation of this study has to do with its internal validity. Indeed, while Hakkarainen's (2003a) level of explanation scale was found very helpful in analyzing and comparing the students' discourse about scientific phenomena, we found it hard to establish agreement between coders. For this reason, we believe it may be a limit to this study.

Finally, the pre- and post-tests and the corresponding rubrics' reliability were not validated by an expert in assessment. The results seem to confirm that they were sensitive enough to identify learning effects but this could also have introduced a confounding factor.

CONCLUSION

Working from remote locations creates new and authentic opportunities for collaborative learning but this particular innovative context faces the same challenges of classroom collaboration: it needs to be effectively supported by the teacher if learning objectives are to be met. In this study, the use of a computer-supported collaborative tool between remote classrooms provided unprecedented opportunities for students to express and share their prior knowledge about scientific phenomena.

The use of the customized scaffold supports embedded in the tool helped students to better understand and put into practice an authentic inquiry process when conducting scientific inquiries. However, specific teacher modeling is needed in order for students to become better at using the prompts coherently to support their inquiry process. Students are capable of suggesting theories and predictions about a phenomenon, but they still need to be taught how to relate those theories to their observations and draw conclusions from the similarities and differences between what was predicted and what actually happened. In doing so, there will be even more opportunities for students to refine their knowledge system about the phenomenon. In order to better support their students' learning process, teachers themselves need to become more comfortable with the inquiry process.

Unless it is already part of the classroom culture, teacher mediation is also needed to support the collaborative conversation online; while the tools themselves make it possible for students to exchange ideas, it does not happen all by itself. Directives to that effect may be needed at first to install effective collaborative learning practices between students of the same group as well as from remote locations. Teachers would greatly benefit from professional development opportunities oriented towards engaging their students in inquiry and supporting a collaborative conversation on scientific topics.

Conceptual change can happen in this innovative learning context provided learning objectives are clear and enough time is devoted to reaching them. As Roschelle said (1992), convergence is the crux of collaborative learning but students will not naturally reach convergence unless they are asked to and given the means to do it. Until additional time is given to science instruction in the Quebec curriculum, the most has to be made of the little time there is. Having students work on theories and predictions about a scientific phenomenon takes time but it is worthwhile. Integrating disciplines, writing and science for example, could be a way to make additional time for science thus allowing students to explore more deeply explanation-generation in order to promote deeper understanding.

Finally, the added challenges of using a computer tool such as Knowledge Forum in daily classroom practices need to be recognized and more seriously addressed by the school authorities. Otherwise, juggling with technical and logistical problems can easily take the teacher's attention and energy from the learning objectives thus depriving them of the opportunity to achieve higher pedagogical goals empowered by the use of computer-supported collaborative tools to support student learning.

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APPENDIX A

Adult consent form

PROJET DE RECHERCHE

L'ÉCOLE ÉLOIGNÉE EN RÉSEAU

Formulaire de consentement informé concernant la participation d'un adulte à cette recherche

La nature et les procédés de la recherche réalisée par le CEFRIO se définissent comme suit:

1. Le Centre francophone d'informatisation des organisations (CEFRIO) conduit un projet visant à accélérer la mise en réseau d'écoles éloignées à des fins d'égalité d'accès et de succès des jeunes à l'éducation. L'objectif de ce projet est double: faire en sorte, d'une part, que l'élève d'une école éloignée dispose d'une plus grande variété de choix de contenus ainsi que d'interactions avec l'enseignant ou des pairs en vue de l'atteinte des finalités du programme scolaire et, d'autre part, que le système éducatif puisse maintenir ouverte les petites écoles de village.
2. Trois chercheurs, l'une de l'Université Laval, un second de l'Université du Québec à Chicoutimi et le troisième de l'Université McGill, sont co-responsables du volet recherche de ce projet.
3. La recherche comprend:
   a. Une collecte de données, portant sur les conditions de mise en route du projet (conditions d'innovation) ainsi que sur les processus de mise en œuvre et ses résultats au plan des croyances et de la compétence pédagogique, sous forme de fiches d'observation, de questionnaires et, dans quelques cas, d'entrevues ciblées (40 minutes chacun et à 4 reprises).
   b. Une collecte de données portant sur des activités en science incluant des tests pour les élèves avant et après l'intervention pédagogique ciblée, jusqu'à concurrence de cinq durant l'année.
   c. Des illustrations multimédia (texte, image, vidéo) d'activités exemplaires.
   d. Une analyse des résultats avec les participants à la fin de chacune des itérations.

Veuillez lire le texte ci-dessous et, si vous acceptez de participer, veuillez indiquer votre consentement en signant le formulaire (voir p. 3) et en le soumettant à la coordonnatrice de cette recherche-action, madame Josée Beaudoin du CEFRIO, soit au responsable délégué par celle-ci. Si vous avez des questions auxquelles vous aimeriez des réponses avant de compléter le formulaire, veuillez envoyer un courriel à Thérèse.Laferrière@fse.ulaval.ca ou à Alain.Breuleux@mcgill.ca ou écrire par la poste à:

Professeure Thérèse Laferrière
Faculté des sciences de l'éducation
Université Laval, Ste-Foy,
McGill,
Qué, G1K 7P4
Téléphone: (418) 656-2131 (5480)
Courrier électronique: tlaf@fse.ulaval.ca
alain.breuleux@mcgill.ca

Professeur Alain Breuleux,
Faculté d'éducation
3700 rue McTavish, Université

Montréal, H3A 1Y2
Téléphone: (514) 398-6952
Courrier électronique:

Le CEFRIO, le Ministère de l'Éducation, l'Université Laval, l'Université du Québec à Chicoutimi et l'Université McGill respectent le code déontologique de recherche et, en tout temps, les intérêts, le bien-être et la sécurité des répondants et répondantes. Ce formulaire, et l'information qu'il comporte, vous est remis pour votre protection et pour vous permettre de bien comprendre les procédures qui seront employées lors du processus. Signer ce formulaire signifie que vous avez eu le temps nécessaire pour lire et comprendre l'information et que vous vous engagez à participer de votre plein gré à ce projet de recherche.

J'ai pris connaissance du présent formulaire, comprends et accepte que les modes de cueillette de données utilisés pour les fins de la recherche seront les suivants:

a) Fiches d'observation – elles seront disponibles partant du serveur de l'équipe de recherche, remplies par les participants à la fin d'activités présentant un caractère de nouveauté et retournées par le participant directement sur le dit serveur électronique qui est sécurisé.
b) Fiches d'observation – elles seront remplies par un ou des membres (maximum 3) de l'équipe de recherche-intervention (ÉRI), présents sur les logiciels *iVisit* et *Knowledge Forum*. Ces données seront conservées sur un serveur électronique sécurisé.
c) Questionnaires – ils seront remplis et renvoyés électroniquement sur le serveur sécurisé à l'automne 2006, en juin 2007 ou en juin 2008, avec des questions portant sur vos impressions, vos idées et vos réflexions et de manière à saisir le maintien ou l'évolution de vos croyances pédagogiques ainsi que des conditions d'innovation à mettre en œuvre pour faire l'école éloignée en réseau.
d) Entrevues – elles seront en nombre limité, ciblées en fonction des besoins d'intervention ou de recherche et elles seront effectuées, pour la plupart, à distance (téléphone ou vidéoconférence).

La participation à cette recherche fournira l'occasion aux participants et à leur communauté locale de réfléchir sur la portée du réseau électronique à des fins d'apprentissage, les nouveaux rôles ainsi que les nouvelles règles s'appliquant. Les bénéfices sont de l'ordre de l'innovation éducative et des retombées pour le système d'éducation québécois et les petits villages du Québec. À noter qu'au Ministère de l'Éducation, cette recherche est considérée prioritaire. Il n'y a aucun risque connu lié à la participation au projet.

En ce qui concerne le caractère confidentiel des renseignements fournis, les mesures suivantes s'appliquent:

a. Le CEFRIO, organisme chargé de la réalisation du projet de recherche, fera signer une entente de confidentialité aux membres de l'équipe de recherche.
b. L'accès aux données électroniques est limité à trois membres de l'équipe de recherche et il leur faudra procéder par code d'identification et mot de passe afin d'accéder à la base de données disponible sur le serveur sécurisé.

Les données seront conservées jusqu'au 31 décembre 2008 sur le serveur, dans des conditions sécuritaires, et alors entièrement détruites. Les illustrations multimédia (texte, image, vidéo) des activités poursuivies devront avoir été autorisées par les participants avant diffusion.

Chaque participante ou participant au volet recherche pourra se retirer de la recherche en tout temps sans avoir à fournir de raison ni à subir de préjudice quelconque.

Il n'y a pas de compensation financière liée à la participation à cette recherche, mais les activités sont réalisées sur le temps de tâche des participants.

Les chercheurs n'ont aucun intérêt financier relié à aucun des logiciels sur lesquels pourrait se retrouver le contenu des échanges électroniques des participants.

La coordonnatrice de la recherche au CEFRIO, madame Josée Beaudoin, peut être rejointe au 550, rue Sherbrooke Ouest, Bureau 350, Tour Ouest,
Montréal (Québec) H3A 1B9,
Téléphone:(514) 840-1245, Télécopieur:(514) 840-1275
Josee.Beaudoin@cefrio.qc.ca

Toute plainte ou critique pourra être adressée au Bureau de l'ombudsman de l'Université Laval à:
Pavillon Alphonse-Desjardins, Bureau 3320
Renseignements – Secrétariat: 656-3081

Télécopieur: 656-3846
Courriel: ombuds@ombuds.ulaval.ca

Toute plainte pourra aussi être adressée au Bureau des plaintes du Ministère de l'Éducation

Je soussigné(e) ______________________________ consens librement à participer à la recherche intitulée: "L'école éloignée en réseau".

Lu et signé le ___________ 2006, à Sainte-Foy (ou Montréal ou autre endroit au Québec)

____
Signature du (de la) participant(e)

____
Signature de la chercheure

No d'approbation du comité: ____________

APPENDIX B

Student consent form

UN PROJET IMPORTANT

L'ÉCOLE ÉLOIGNÉE EN RÉSEAU

CONSENTEMENT D'UNE PERSONNE MINEURE

À ÊTRE SIGNÉ PAR LE PARENT OU LE TITULAIRE DE L'AUTORITÉ PARENTALE

Saviez-vous que la commission scolaire de votre enfant participe au projet de l'*École éloignée en réseau* lancé par le ministère de l'Éducation du Québec dans des petits villages? Ça signifie qu'au cours de la présente et de la prochaine années scolaires, l'école, en collaboration avec un centre spécialisé dans l'usage de l'Internet (CEFRIO), mettra en place de nouveaux moyens pour favoriser les apprentissages et la réussite de votre enfant. Deux logiciels ont été retenus à cette fin: le KF pour la lecture et l'écriture et *iVisit* pour la communication par vidéoconférence. Ces logiciels ont été utilisés dans treize sites-pilotes au cours des deux dernières années et ils ont été fort utiles pour faire progresser les élèves dans leurs connaissances, les faire travailler en équipe et les responsabiliser lorsqu'ils utilisent Internet pour faire des activités dans le cadre de leur programme scolaire.

De plus, le Ministère a confié au CEFRIO le mandat d'étudier cette innovation. À cette fin, le CEFRIO a conclu des contrats avec l'Université Laval, l'Université du Québec à Chicoutimi et l'Université McGill pour s'assurer de la collaboration de leurs équipes de chercheurs qui seront chargés de la collecte et de l'analyse des données de recherche.

Nous avons besoin de votre consentement

Bien sûr, nous aimerions compter sur la participation de votre enfant, car sans la coopération des élèves, il sera impossible de réaliser cette étude. C'est pourquoi nous vous demandons de signer le présent formulaire. Votre signature attestera de votre consentement à la participation de votre enfant à cette étude, notamment en autorisant les chercheurs à observer son utilisation des logiciels, à lui poser des questions, oralement ou par écrit, et à consulter son dossier scolaire de base (résultats scolaires, bulletins, fiche d'inscription).

Tout comme vous, votre enfant a le choix

Autre précision importante: tout comme vous, votre enfant peut accepter ou refuser de participer à cette étude qui se poursuivra jusqu'en juin 2007. Notez bien qu'en tout temps vous pouvez retirer votre consentement. Le refus de participer n'aura aucune conséquence fâcheuse. Quelle que soit votre décision, votre enfant bénéficiera, comme les autres élèves, des activités réalisées dans le cadre de *l'École éloignée en réseau.*

Qu'est-ce qu'on attend de votre enfant?

- il sera invité à deux reprises à passer un test de lecture (40 minutes).
- Il sera invité à passer un test (avant et après l'intervention pédagogique) sur des thèmes scientifiques vus en classe jusqu'à concurrence de cinq fois

Confidentialité, droit d'accès et de rectification

La loi protège tous les renseignements personnels recueillis au cours de cette étude. À l'exception des renseignements accessibles au personnel enseignant dans le cours normal des activités pédagogiques, seul le personnel de recherche aura accès aux renseignements révélés par les réponses aux questionnaires et les entrevues. À noter que toutes les feuilles remplies par votre enfant seront détruites au 31 décembre 2008. Enfin, en vertu de la loi, un organisme public est tenu de vous donner le droit d'accès et de rectification à l'égard de tous les renseignements personnels qu'il détient sur vous ou votre enfant.

J'accepte que mon enfant participe au projet *L'école éloignée en réseau* selon les modalités décrites dans la présente lettre d'information.

Nom de l'enfant (en lettres moulées)
Nom du signataire

Signature du parent ou du titulaire de l'autorité parentale
Date

Nous avons une demande de plus à vous faire

Nous ferons quelques montages de situations exemplaires à partir d'extraits des textes des élèves, de photos et de séquences audio et vidéos. Accepteriez-vous que de tels documents écrits, audio ou visuels de votre enfant soient montrés sur le site web du projet (www.eer.qc.ca) à titre d'exemple de ce que les jeunes arrivent à réaliser avec les logiciels utilisés? Seules des situations qui avantagent votre enfant en train d'apprendre seront montrées publiquement, soit lors de communications auprès de professionnels de l'éducation ou dans un rapport publié sous format papier ou sur Internet. En aucun cas le nom de votre enfant ou le nom de l'école qu'il fréquente ne seront dévoilés. Si vous êtes en accord avec cette seconde demande, nous vous invitons à prendre connaissance de la formule de consentement reproduite au verso et à la signer.

1

Verso

J'ai pris connaissance de la présente lettre d'information concernant le projet *L'école éloignée en réseau* et je consens à ce que les documents écrits, audio ou visuels de mon enfant qui seront recueillis au cours de la recherche puissent être publiés et diffusés selon les modalités décrites ci-dessus. À cette fin, je cède gratuitement au CEFRIO, à l'Université Laval, à l'Université du Québec à Chicoutimi et à l'Université McGill, les droits d'utilisation de ce matériel, pour les fins et de la manière qui y sont indiquées. Conséquemment, des extraits du travail de mon enfant pourront être reproduits, exposés, publiés, vendus ou distribués d'une façon ou d'une autre (par exemple, de manière électronique ou sur format papier), et en un lieu ou l'autre. En tout temps, d'ici juin 2008, je me réserve le droit de révoquer le présent consentement et la cession de droits dont il est assorti, sans aucune pénalité.

Nom de l'enfant (en lettres moulées)
Nom du signataire

Signature du parent ou du titulaire de l'autorité parentale
Date

APPENDIX C

Inquiry test

Nom de l'élève:
Nom de l'enseignante:
Date:

Directives:
1. Lis toutes les questions une première fois avant de commencer.
2. Prends ton temps pour répondre à chaque question de ton mieux.
3. Il n'y a pas de bonne ou de mauvaise réponse, ces questions vont nous aider, ton enseignant(e) et moi, à savoir ce que tu penses, tout simplement!

1) Qu'est-ce que c'est pour toi la science?

2) Est-ce que tu aimes apprendre les sciences? Pourquoi?

3) Qu'est-ce que c'est pour toi une théorie? À quoi ça sert?

4) Qu'est-ce que c'est pour toi une prédiction? À quoi ça sert?

5) Pourquoi fait-on des expériences en sciences? À quoi ça sert?

6) Est-ce qu'il y a un lien, selon toi, entre les théories, les prédictions et les expériences, en sciences? Quel est ce lien?

Merci !!

APPENDIX D

Rubric for the Inquiry Test

Score	0	1	2	3
Rubric	No answer; Incoherent, incomplete and incorrect answer; Answer without any scientific content;	Complete but incorrect answer without any scientific content; Incoherent example;	Incomplete but correct answer; Complete but partially incorrect answer; Complete and incorrect answer but with scientific content; Coherent example	Complete and correct answer;
Examples from Question 1: «Qu'est-ce que c'est pour toi la science? » *What is science to you?*	« Rien » *Nothing* « Pas grand chose » *Not much* « Je ne sais pas » *I don't know* « ? »	« Quelque chose que tu étudies. » *Something you study.* « Une activité qui permet d'apprendre » *An activity that makes you learn* « Chercher des informations. » *Searching for information* « Faire des découvertes, apprendre des nouvelles choses... » *Discover things, learn new things...* « [Pour] moi les sciences veulent dire apprendre comment manipuler le choses. » *To me science means learning how to manipulate things*	« C'est quelque chose de très complexe tout est une forme de science la science du corps humain etc... » *It's something very complex everything is a for of science science of the humain body, etc...* « C'est pour expliquer quelque chose là où il y a des produits chimiques et des réactions (exemple: bicarbonate de soude et vinaigre » *It's to explain something where there are chemical products and reactions (example: sodium acid carbonate and vinegar)* « C'est quelque chose d'important qui dit aux gens ex: la planète se détruit faites moins de pollution. » *Something important that tells people ex: the planet is being destroyed stop polluting*	« La science pour moi c'est des expériences qui nous fait apprendre des nouvelles choses » *Science for me is doing experiments to learn new things* « Une matière qui sert à apprendre des choses par rapport à la nature » *A discipline to learn things related to nature* « Un moyen de connaître plus notre environnement » *A way to better know our environmnent* « C'est des expériences avec plusieurs choses ce n'est pas seulement des petits volcans en éruption c'est connaître plus de choses sur presque tout. » *It's experiments with a lot of things not just small erupting volcanos it's knowing more things about nearly everything*

APPENDIX E

Buoyancy and relative density test

Nom de l'élève:
Nom de l'enseignant(e):
Date:

Directives:
1. Lis toutes les questions une première fois avant de commencer.
2. Prends ton temps pour répondre à chaque question de ton mieux.
3. Il n'y a pas de bonne ou de mauvaise réponse, ces questions vont nous aider, ton enseignant(e) et moi, à savoir ce que tu penses, tout simplement!

1) Selon toi, pourquoi certains objets coulent dans l'eau et d'autres flottent sur l'eau?

2) Si tu mets une bille de verre, une petite cuillère en métal, et une orange dans un bac rempli d'eau, qu'est-ce qui va flotter sur l'eau et qu'est-ce qui va couler au fond?

Flotte:

Coule:

3) Pourquoi?

4) Qu'est-ce que c'est pour toi la densité d'un objet?

5) Quel est le lien entre la densité d'un objet, la densité d'un liquide et le fait que l'objet flotte ou coule dans le liquide?

MERCI !!

APPENDIX F

Rubric for the buoyancy and relative density test

Score	0	1	2	3
Rubric	No answer; Incoherent, incomplete and incorrect answer; Answer without any scientific content;	Complete but incorrect answer without any scientific content; Incoherent example;	Incomplete but correct answer; Complete but partially incorrect answer; Complete and incorrect answer but with scientific content; Coherent example	Complete and correct answer;
Examples from Question 1: « Selon toi, pourquoi certains objets coulent dans l'eau et d'autres flottent sur l'eau?» *Why do you think some objects sink in water while others can float ?*	« Je n'ai aucune idée » *I have no idea* « Je ne sais pas » *I don't know* « ? »	« Parce que les objets qui coulent sont faits de matériaux qui coulent et c'est la même chose pour le contraire» *Because objects that sink are made of materials that sink and the same is true for the opposite.* « La forme de l'objet.» *The object's form.* « Ça dépend de la matière avec lequel l'objet est fait.» *It depends on what the object is made of.*	« Poids de ton objet, un objet lourd va caller et un objet léger va flotter.» *Weight of your object, a heavy object will sink and a light object will float.* « À cause de l'aire qui Circule à l'intérieure, et aussi si il est plus lourd que la place qu'il occupe il va couler ou au sens contraire il va flotter» *Because of the air that circulates inside, and also if it is heavier than the place it occupies it will sink or if it's the opposite, it will float.* « Parce que ça dépend de la quantité d'air et la forme de l'objet qui fait sa différence.» *Because it depends on the quantity of air and on the form of the object that makes a difference*	« Car il y en a qui sont rempli d'air ou l'objet dans leque il flotte est plus dense» *Because some are full of air or the object in which it floats is dense.* « Le poid et la masse volumique des objets » *The object's weight and density.* « Moi je pense que c'est à cause de la densité de l'eau et de l'objet qui fait que les objets coulent.» *I think that it's because of the water and the object's density that objects sink.* « À cause, de la densité si l'objet est plus dense il coulera et si il est moins dense il flottera. ex: Bois: les molécules sont moins denses que le fer alors le bois flottera. Et le fer coulera.» *It's because of density if the object is more dense it will sink and if it is less dense it will float. Ex.wood: the molecules are less dense than iron so wood will float. And iron will sink*

APPENDIX G

Discussing Buoyancy - Exerpt 1 (EN)

1.2 Students 1, 2 and 3:
L'eau fait son rôle et essaie de retenir l'objet à la surface et quand l'objet est rond l'eau ne pourra pas le retenir car il n'a pas de grande surface. Plus c'est rond et lourd plus ça coule.

The water plays its role and tries to retain the object at the water surface and when the object is round the water will not be able to retain it because it doesn't have a big surface. The more it's round and heavy the more it sinks.

La densité est que deux objets du même poids un plat et un rond. Le rond reste à la surface et le plat coule. C'est grâce à la densité. plus que l'objets est rond et lourd il va couler. plus qui est lourd et plate plus que l'eau ne pourra pas le retenir.

Density is that two objects of the same weight one is flat and one is round. The round one stays at the surface and the flat one sinks. This is because of density. The more the object is round and heavy, the more it will sink. The more it is heavy and flat the more the water will not be able to retain it.

1.2.1 Researcher:
OK donc selon vous, si l'objet est plat, il va couler. Mais pourquoi un radeau plat arrive-t-il donc à flotter?? Vous avez une partie de la solution... Expliquez-moi le rôle de la densité dans tout cela...

OK so according to you, if the object is flat it will sink. But why is a raft able to float ?? You already have parts of the answer... Tell me the role of density in all of this..

1.2.1.1 Students 1 and 3:
Un radeau ne coulerat pas parce qu'il a une grande surface donc l'eau peut le retenir. La densité désigne le poids et la surface de l'objet. Elle déside si l'objet coule ou pas.

A raft will not sink because it has a big surface so the water can retain it. Density designates the weight and surface of the object. It decides whether the object sinks or not.

1.2.1.1.1 Researcher:
Peux-tu m'expliquer en quoi la densité influence si l'objet coule ou pas? Tu as beaucoup d'éléments de réponse dans ta note déjà...

Can you explain to me how density influences whether the object sinks or not ? You already have parts of the answer in your note...

1.2.1.1.1.1 Student 1:
Moi je pense que plus que l'eau est dense plus que l'objet va flotter et moins que l'eau est dense plus qui va couler.

I think that the more the water is dense the more the object will float and the less the water is dense the more it will sink.

APPENDIX H

Discussing Buoyancy - Exerpt 2 (EN)

1.6. Students 4, 5, 6 and 7:
Student 4: *Moi je dit que c'est parce que l'objet qui flotte contien de l'air.*
EX: Si tu remplis une bouteille d'eau au complet jusqu'au bord avec son bouchon elle coulera car ele ne contien plus d'air. Mais si tu remplis la bouteille jusqu'à 4 cm du bord seulement le 4 cm pas d'eau mais d'air va faire flotter la bouteille mais la partie avec l'eau elle sera couler...la partie avec l'air elle flottera parecsempe... et si tu mais une bouteille vide (toujours avec le bouchon car pas de bouchon l'eau se remplis et fait sortir toute lair alors quand lair sera toute sortie alors biensur la bouteille va couler) va flotter toute au complet hors de l'eau.Et je dit que il n'y a aucun raport avec le pois et/ou la grosseure de l'objet

I think that it's because the object that floats contains air. EX. If you fill a bottle of water completely to the rim with the cap it will sink because it will no longer contain air. But if you fill it up to 4 cm off the rim, the 4 cm of air will make the bottle float but the part with water will sink... the part with air will float however... and if you put an empty bottle (with the cap on because without the cap the water will fill it up and the air will leave the bottle and when all the air is gone then of course the bottle will sink) will float completly out of the water. And I say that there is no relationship between the weight and/or the size of the object.

Students 5, 6, and 7:*On trouve que les choses plus lourdes comme les roches ça coulent et les choses plus légères flottent.*

We believe that heavier things like rocks, sink and lighter things float.
1.6.1 Researcher:
Si je vous comprends bien, les objets lourds coulent et les objet légers flottent... Mais pourquoi de gros bateaux réussissent-ils à ne pas couler, alors?

If I understand you correctly, heavy objects sink and light objects float... So, how come big boats do not sink ?

1.6.1.1 Student 6:
Parce que il ya des l'air dans le Bateau

Because there is air in the boat.

1.6.1.1.1 Researcher:
Peux-tu m'expliquer ce qui fait que l'air dans le bateau lui permet de flotter sur l'eau même s'il a une masse très importante?

Can you explain to me how the air in the boat can make it float on the water even with a very important mass ?

APPENDIX I

Discussing Buoyancy - Exerpt 3 (EN)

2.1. Student 8:
La boule lache va flotter et la boule serré va coulé.
Mes observations on an eu raison

The looser ball will float and the tighter ball will sink… My observations we were right.

2.2 Student 9:
on avait pas raison la boule lâche a flotter et la boule serrée a couler.

We were wrong the loose ball floated and the tight ball sank.

2.3 Student 10:
la boule compactée a callée parce que il navait pas d'air dedans et l'inverse pour l'autre.

The tight ball sank because there was no air in it and the opposite for the other.

2.4 Students 11, 12, 13 and 14:
la boule qui etait chifoner ne coulai pas il avai boucoup d'aire dedans et celle qui etait plate avais moin d'aire dedans et elle etais plate et sa couler vite a cause que leau rentrai vite

the crumpled ball did not sink there was a lot of air in it and the flat one had less air in it and it was flat and it sank quickly because water entered quickly

2.4.1 Student 15:
moi je crois que la boule compressée n'a pas coulée parce que l'eau rentrait dedans mais parce qu'il n'y avait pas d'air dedans et qu'elle était plus lourde que la place qu'elle occupait.

I believe that the crumpled ball did not sink because water entered it but because there was no air in it and it was heavier than the space it occupied.

2.5 Students 15, 16, 17 and 18:
Nous croyons que la boule lâche va flotter car elle a de l'air à l'intérieur.Par contre, la boule serrée va couler car elle n'a pas d'air à l'intérieur d'elle.Nous croyons aussi que la boule lâche pourrais flotter car elle est aussi lourde que la place qu'elle occupe sur l'eau.La boule serrée pourrait couler car elle est plus lourde que l'espace qu'elle occupe.

We believe that the looser ball will float because it had no air in it. However, the tight ball will sink because there is no air in it. We also believe that the looser ball will be able to float because it is as heavy as the air it occupied on water. The tight ball may sink because it is heavier than the space it occupies.

2.5.1 Students 15, 16, 17 and 18:
Après l'expérience, nous avons remarqué que nos prédictions étaient juste.

After the experiment, we noticed that our predictions were true.

APPENDIX J

Discussing Buoyancy - Exerpt 4 (EN)

7.6 Students 19 and 20:
notre équipe est diviser en deux nous nous croillon que l'oeuf va flotter dans l'eaux saler et l'autre moitier croix que l'oeuf va flotter dans de la mélasse.l'oeuf va fotter pcq il va il va etre surparter par l eau salée.l autre équipe pense que sa va fotter pcq la mélasse est épaise.

Our team is divided in two we believe that the egg will float in the saline water and the other half believes that the egg will float in molasses. The egg will float because it will be supported by the saline water. The other team thinks that it will float because molasses is thick.

7.6.1 Students 19 and 20:
Mes observations après l'expérience nous avons vues que l'oeuf des de l'eau salé (unpeu moin que une demi tasse de sel et 2 tasse d eau) pcq dans la mer ont flotte et c'est de l'eau salée. ont avons réussi !!!!!!!!!

My observations after the experiment we say that the egg in the saline water (a little less than half a cup of salt and 2 cups of water) because in the sea we float and its saline water. We succeeded !!!!!!!!

7.6.1.1 Teacher:
Avez-vous vérifié pourquoi on flotte plus facilement dans de l'eau salée? Allez sur wikipedia et cherchez mer morte....
Did you verify why we float more easily in saline water ? Go to wikipedia and look up Dead Sea...

7.6.2 Students 21 and 22:
l'oeuf flotte parce que la mélasse est plus dense que l'œuf

The egg floats because molasses is denser than the egg.