Education research has shown the importance of helping students develop deeper understanding in order for them to be better prepared for tomorrow's knowledge society (Bereiter, 2002; Bransford, Brown & Cocking, 2000; Drucker, 1993; UNESCO, 2008). However, too often students are asked to say what they know rather than explain and connect their knowledge (Sawyer, 2006; Wiske, 1998a). Therefore, the challenge for educational reform is to design learning environments to be more centered on student learning and for them to reach a deeper level of understanding.

Explanation-seeking rather than fact-seeking pedagogies have been shown to warrant deeper student understanding (Bransford, Brown, & Cocking, 2000; Coleman, 1998; Hakkarainen, 2003; Hatano & Inagaki, 1987; Roth, McGinn, Woszczyna, & Boutonné, 1999) and some technological tools, like the Knowledge Forum, are able to support explanation-seeking pedagogies and the inquiry process (Bereiter & Scardamalia, 1996; Brown, Ellery, & Campione, 1998; Hakkarainen, 2003). In science education specifically, explanation-seeking pedagogies have proved efficient (Coleman, 1998; Hatano & Inagaki, 1987; Kracjik, Soloway, Blumenfeld, & Marx, 1998; Roth et al., 1999).

In light of this, how can the use of technology in the classroom improve the explanation skills of students, thus permitting them to acquire the essential knowledge of the curriculum? We claim that one way for that to occur is to work with a technological tool that allows scaffolding of student inquiry focused on knowledge building rather than knowledge telling (Bereiter, 2002) and designed to support the collaborative investigation of authentic problems (Chin & Osborne, 2010; Scardamalia, 2006). In this regard, the collaborative nature of learning as well as the support of the community of learners (Brown & Campione, 1994) is important aspects to consider in the design of the learning environment (Rummel & Spada, 2005). Indeed, we know that students learn by interacting with technology and with their peers. The use of technology in the web 2.0 world reminds us that we are not alone in front of our computer screens; schools can thus profit from this connectedness to enrich the learning environment of their students. It is thus important to consider whether we should require students to power down their personal technological devices or not as they enter into the classroom, a restriction likely to contrast with what they experience everywhere else in their lives.

The Context of the Study

The Remote Networked Schools (RNS) initiative in the province of Quebec (Canada) aims to enrich the learning environment of small rural schools by providing students and teachers with more opportunities for interaction through the use of telecollaborative technologies. Given a substantial decline in population and rural exodus, these rural schools face many issues: lack of specialized resources for students, multilevel classrooms, small numbers of registered students and professional isolation. In 2010, involvement in this initiative included twenty-three school districts, more than 200 schools, 170 teachers and over 2000 students. Since 2002, two telecollaborative tools have been available to the participating classrooms: an easy to use desktop videoconferencing tool (iVisit) and Knowledge Forum, a discussion forum based on the theory of knowledge building (Scardamalia, 2004).

Classes involved in the RNS initiative have worked collaboratively with these tools through the process of idea improvement reflective of deeper understanding and anchored in the school curriculum. Over the years, several professional development sessions were offered to teachers regarding authentic and open questioning and collective knowledge building as well as student-centred learning environments. Skilled resource people were available for just-in time help all day long regarding the planning of learning activities, reflection on the progress of specific collaborative activities and the setting of goals for improving student writing and knowledge building ability (Authors and colleague, in press).

After six years (2002-2008) of implementation, the use of the telecollaborative tools became a part of RNS classroom practices (approximately a third of classroom time). Impact measurement of the initiative included student motivation, development of innovative practices and organizational changes (Colleague and authors, 2006; Authors and colleagues, 2004, 2009 ; Authors, 2008). Some teachers reported that students who were more active users of the KF were more successful and further developed their explanation skills than other less active KF users. This was the impetus for the study presented here, i.e. to focus on the use of KF and confirm (or not) its perceived impact on student learning.

We knew of an increase in student motivation regarding writing (Authors and colleagues, 2011), and teachers were reporting evidence of a real-audience effect, especially regarding science and technology activities supported by KF (Authors and colleagues, 2009). There was some knowledge building but teachers wanted to validate their perceptions regarding the development of individual skills as a result of involvement in these online activities. Were students individually able to explain what they had collectively discussed in KF? Were they able to apply the shared knowledge in other contexts? In order to answer these questions, we set up this study with schools that wanted to validate their assumptions regarding the impact of using the forum on student learning. The research questions addressed in this study are the following:

- Can the use of the knowledge building tool contribute to the development of K-6 students explanation skills? If so, how?
- Can different levels of KF use lead to different levels of explanation skills?
- Can the students' level of explanation in their collaborative work on the KF have an impact on their score?

Methodology

In order to verify our assumptions about KF use and student learning, we decided to conduct a mixed method experiment. This paper presents the results of two different discourse analyses, the results of which were quantified. Then, we triangulated this quantified qualitative data with quantitative data related to student KF use. Therefore, both quantitative and qualitative analyses were conducted in this study. This study, conducted with interested teachers from four RNS school districts allowed us to look more closely at the use of KF with regard to student learning, with a specific focus on their explanatory skills.

In order to answer our research questions, we designed pre-and post-activity interviews to assess students' knowledge as well as their ability to explain certain phenomena in three subject areas: science and technology, social sciences, and ethics and religious culture[1]. Teachers informed us of their pedagogical intentions in relation to the curriculum but they were not aware of the interview questions until after the post-interviews were conducted. When we could not interview the entire class, we asked teachers to select nine of their students for the interviews: three students at three different levels of ability. The interviewers were not aware of the students' level of ability throughout the experiment. This teacher selection allowed us to avoid interviewing only the stronger students (social desirability). We conducted one-to-one interviews with students before and after the activity. The interviews took the form of oral tests on the topics explored and, specifically, required students to explain the topics they were going to explore (or

[1] The Quebec ethics and religious culture program is a unique subject area that aims to explore ethics-related topics and different religious cultures from a secular perspective and with a dialogue-oriented approach (Éthier & Lefrançois, 2010).

had explored) in class. For example, students to work on the climates were asked: Are the alternating seasons the same everywhere in the world? Why?

Between the pre and post-activity interviews, 22 classrooms worked in the KF. Table 1 presents the participants of this study. Three classrooms did not work on the KF during that period of time because their teachers encountered technical or availability of time related problems. Since their students were interviewed before and after their activity, just like the other students, we decided to use them as a control group. Most of the teachers used authentic questioning strategies to foster students' understanding (Wiske, 1998a, 1998b) of various phenomena linked to the curriculum (Authors and colleagues, 2011). Among these schools, some are located in socio-culturally and economically disadvantaged areas and struggle with high dropout rates and serious problems with academic motivation. Altogether a total of 289 students were interviewed twice. We collected data up to two weeks after the completion of the learning activities.

Table 1.

Participants in the study

School Board	Classrooms	Students - Experimental	Students - Control
4	25	251	38

Students' responses to the pre- and post-activity interviews were analyzed qualitatively for the quality of the explanation provided (McNeill et al., 2006; Author, 2008). Table 2 presents the coding rubric of this analysis. Interrater agreement was achieved between three coders to ensure the validity of the coding (Miles & Huberman, 1999[2]) with an average rate of 93% for the three learning domains (science, social science, and ethics and religious culture). This qualitative analysis allowed us to generate quantitative results illustrating the quality of explanations given for each of the students interviewed.

[2] The number of agreements (A) divided by the number of agreements plus disagreements (D) (A / (A+D)).

Table 2.

Rubric for the pre- and post-activity interviews

Score	Rubric	Definition
0	No explanation	No answer; Incoherent, incomplete and incorrect explanation
1	Partial explanation	Incomplete but correct explanation; Complete but partially incorrect explanation;
2	Complete explanation	Complete and correct explanation

Concurrently, we analysed the work done by the students in the KF. First, we found large differences in the use of the forum, especially in the number of notes written and read by students during the activity. The KF provides applets to analyze the use of affordances in this online collaborative environment, such as the number of written contributions per student, the number of contributions read, the use of scaffolds, keywords, etc. Using the data collected by the analytical toolkit, a cluster analysis confirmed two different user profiles based on the average use of the key KF affordances. Table 3 presents the students' user profiles according to their KF use.

Table 3.

Definition of the two students' user profiles in the KF

	Profile 1 (Low Users) n=240		Profile 2 (Active Users) n=30	
Affordances	Mean	Definition	Mean	Definition
Number of written notes	2.36	Students write few notes	16.72	Students write several notes
Number of notes read	15.75	Students read few notes	158.1	Students read several notes

Statistical analyses

When the coding phase was complete, we proceeded by conducting several statistical analyses on our dataset. First, as stated earlier (see Table 3), a cluster analysis had helped us define two distinct user profiles (n=251). This analysis of the KF database (notes created, notes read, etc.) was consistent with our perception and our knowledge of the field and allowed us to formalize the user profiles. We later added a control group with unplanned non-users. Indeed, the control group includes students who were planning to use the tool for an activity, who were interviewed prior to the activity and after it was over, but who ended up not using the KF for different reasons.

First sets of analyses were conducted on the smaller dataset (i.e. excluding the control group). A repeated measure ANOVA was conducted on the pre- and post-activity interviews scores. The independent variables included gender, group, level of explanation (KF), user profiles and test time. A prior ANOVA on the pretest scores was also conducted and showed a significant effect of group and profile i.e. that the groups (i.e. classrooms) and profile users were not equal prior to the analysis. Indeed, profile 2 users, the most active, fared much lower on the pretest.

A second set of analyses was conducted on the entire dataset (i.e. including the control group). This analysis allowed us to further illustrate the effect of using the KF, even to a lesser degree, on students' oral explanation skills. In this analysis, the dependant variables were gender, group, user profiles and test time. Here too, an ANOVA on pretest oral scores showed a significant effect of group and user profile.

Results

First, the repeated measures analysis showed a significant effect of test ($F_{(1, 148)}$ =114.40, $p<0.000$) on the overall scores, i.e. that student oral explanation scores improved significantly between the pre-and post-activity interviews (Figure 1). Indeed, the estimated marginal means go from 51.13% on the pre-activity interview to 64.01% on the post-activity interview. Across groups, students were able to better explain what they understood of the phenomena being studied after the activity was completed than they were before. The improvement in the explanatory competencies of students between the two measurement times was not taken for granted. This result reassured the participating teachers and us because student explanation was not the usual focus of classroom activities and we wondered if there would be such an effect at all. For this reason, we were glad to observe this effect for all the groups.

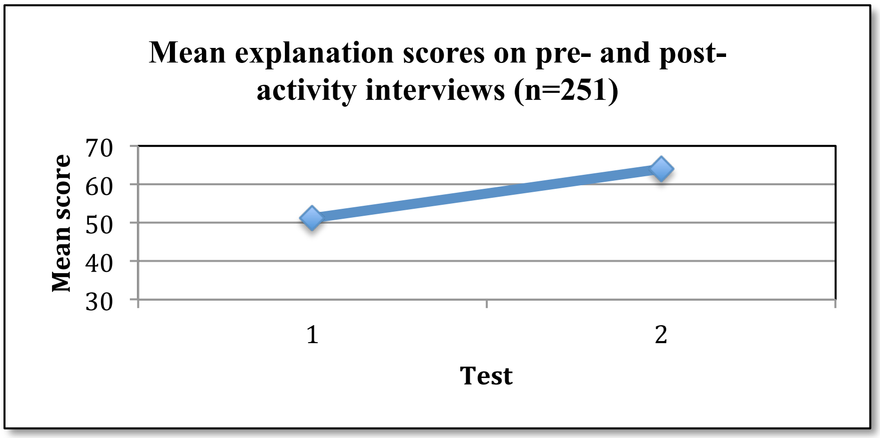

Figure 1. Estimated marginal means on pre- and post-activity interviews

The analysis also showed a significant user profile effect ($F_{(1, 148)}$ =4.83, p=0.030). As illustrated by Figure 2, Profile 1 students estimated mean score on the pre-activity interview was 52.13 % and it was 63.81% on the post-activity interview, meanwhile, Profile 2 students scored a mean of 34.93% for the pre-activity interview and 67.22% for the post-activity interview. This means that student profiles, which take into account their use of the KF affordances and their overall involvement in the collaborative discourse, significantly impacted their individual results of the post-activity interview. Indeed, Profile 2 students, who had a significantly lower mean test score at the start of the study, finished with a significantly higher mean score than Profile 1 students.

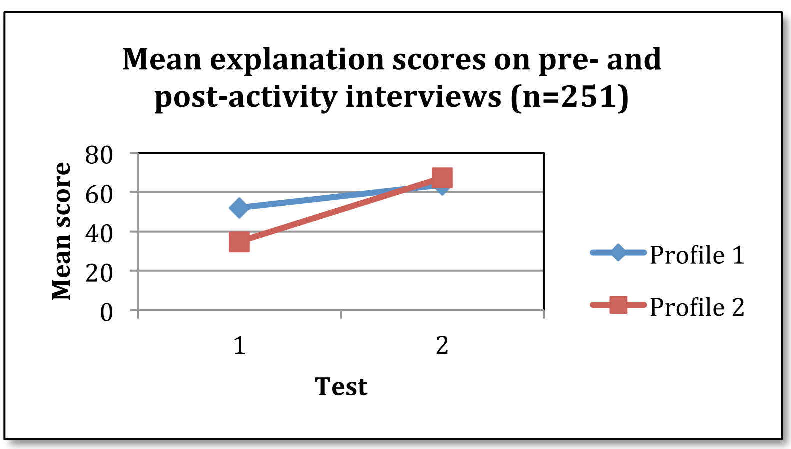

Figure 2. Estimated marginal mean explanation scores on pre- and post-activity interviews according to student profiles

A second repeated measures ANOVA included a control group. The estimated marginal means for the control group was 47.46% for the pre-activity interview and 56.22% for the post-activity interview. These estimated means clearly show that not only did control group students score lower on both interviews, they also improved less than the two KF user profiles between the interviews. As we can see from the slopes in Figure 3, students who used the KF (Profiles 1 and 2) performed better on their post-activity interviews. But what is even more striking is how important the improvement was for Profile 2 students: these students scored much lower on their pre-activity interviews and were able to surpass the other students on their post-activity interviews. These results alone confirm our longstanding impression that more active KF users individually gained from their collective written interactions.

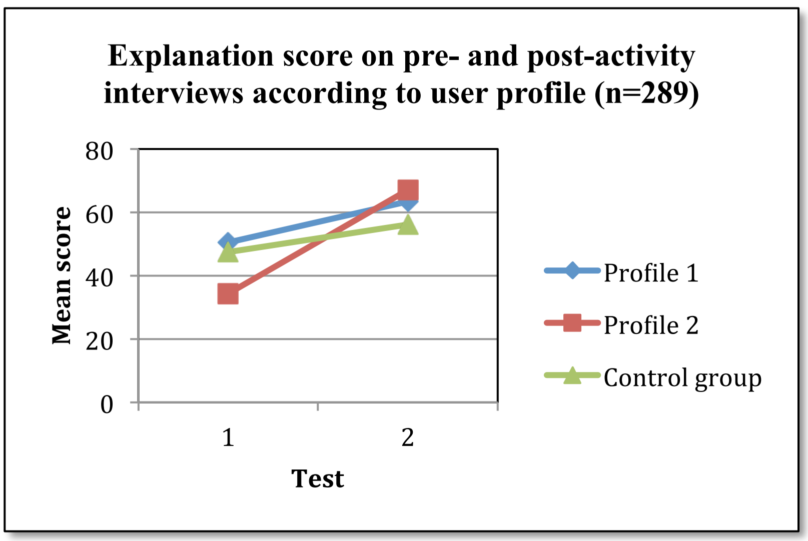

Figure 3. Estimated mean explanation scores on pre- and post-activity interviews according to students' profiles

Discussion

The aim of the study was to validate teachers' perception that students who were active users of the KF were learning more and further developed their explanation skills. It also hoped to confirm (or not) the researchers' belief that a collaborative knowledge building tool such as KF would not only enrich the learning environment of students but that such collective efforts would lead to better individual student learning.

The importance of this study is clear. Although past reports of RNS results have discussed different topics such as student motivation (Authors & colleagues, 2008; Authors & colleagues, 2011), conditions of innovation (Authors, 2008; Author, 2011), new classroom practices (Author and colleagues, 2004; Authors & colleagues, 2006), innovative forms of professional development (Authors and colleagues, 2009; Authors and colleague, in press), and multi-level decision-making processes (Author, 2011; Authors, 2012), this study provides clear empirical evidence that link educational innovations centered on collaborative work to individual student learning, a connection that had yet been empirically proven.

Furthermore, this study relies on a solid design linking repeated student interviews on the one hand, and collaborative writing on the other. The number of cases is also impressive: nearly three hundred students, from different schools and schools districts all over the province were conducted and then analyzed. A cluster analysis confirmed the researchers' observations in the field as regards KF users and this allowed us to create user profiles formally, a difficult task in itself considering the tremendous number of variables in our particular research context. This mixed design allowed us to benefit from the strengths of both methodologies: the qualitative analysis of the students' collaborative online discourse and individual pre- and post-activity interviews gave us a better insight on student learning and explanation capacity. Quantitative analyses allowed us to generate clear answers to our research questions. These analyses, combined with the teachers' perceptions, have allowed us to benefit from a triangulation of methodologies that further validates our findings.

Indeed, our results show that infrequent users improved about as much as non-users, and this confirms that in order to get results, the use of the tool must reach a certain level. It is not infrequent for teachers to want to "start small" with this kind of innovation. For example, they will choose to use the KF to prepare activities for Christmas or Halloween, hoping that if it "doesn't work", at least it will not interfere with more "serious knowledge". Our own intervention approach suggests instead to work on central parts of the curriculum rather than peripheral ones. We believe that in doing so, students as well as teachers will benefit from the activity faster, but that it will also be the best way to make the most of the time spent using the tool. No school time is worth wasting.

As we expected, writing one or two notes once in a while is not enough for students to improve their explanation skills. If we look at it more closely, Profile 2 students mostly came from two groups whose teachers both incorporated networking activities in their daily routine up to one hour each day. In these two groups, students spend as much as one hour each day reading, writing and collaborating on the KF on various school topics and authentic questions. The teachers also mentioned that with the KF, they participate more than other groups in authentic reading and writing activities (Authors and colleagues, 2011). Clearly, active use of the KF leads to greater improvement of student explanation skills.

The fact that Profile 1 (Figure 3) students, just like the control group, have shown less progression in students' explanation skills than Profile 2 students raise a new series of questions: Is effective classroom collective inquiry bound to the use of KF or another similar online collaborative space? Does this mean that the investigations that were essentially of a verbal nature had less of an impact on students' explanation skills? Reading and writing in a greater proportion may have developed the students' ability to make connections between concepts and knowledge (Bereiter, 2002). Students may have interacted more among themselves in a written form than verbally (see Cazden, 1988). However, we doubt that teachers were as rigorous in respecting the structure of the inquiry when they relied only on verbal classroom interaction (and other forms of exercise from textbook). One limit of this study is that we have no data on the structure of classroom verbal discourse. Did it fall back on the standard I-R-E (Initiation-Response-Evaluation) structure (Cazden, 1988)?

The results of this paper were presented to the participating teachers as well as to the entire RNS network. Emphasis was put on the need for students to work with a certain frequency using the KF before starting to see definite results on student learning. There was a general acknowledgement that the challenge is still a major one for the RNS network, that is, to significantly increase the time spent using the KF so that students may have more opportunities to experience knowledge building/creation (Scardamalia & Bereiter, 2010).

Conclusion

This study provides strong empirical evidence that the informed use of a knowledge building tool to support student collaborative learning was able to significantly improve student explanation skills. However, low use of the KF was not linked to such improvement, confirming that a certain level of online activity is necessary in order to achieve such results. Indeed, a minimal use of the tool such as described by Profile 1 users (see Table 3) has generated as much improvement as the control group, which did not use the tool at all. This confirms our belief that in order to get significant results, teachers have to focus on central elements of the curriculum and get their students to read and write to a certain degree. Minimal efforts will generate minimal results.

This study also provides empirical evidence that explanation-based rather than fact-based online collaborative discourse led to greater improvement between pre- and post-activity interviews, even for students who had significantly lower results at the onset. Even when most of these active students come from low SES communities.

For the last ten years, the RNS initiative aims to enrich the learning environment of the students. These results show that frequent and quality interactions supported by the Knowledge Forum can lead to the improvement of students' explanation skills, and to deeper understanding. The RNS initiative also shows how emerging technologies and globalization enable universities to develop new ways to support professional development in schools and other fields.

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