

Can a Hypermedia Cooperative e-Learning Environment Stimulate Constructive Collaboration?

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ABSTRACT

The growing use of the Internet in learning environments has led to new models being created addressing specific learning domains, as well as more general educational goals. In particular, in recent years considerable attention has been paid to collaborative learning supported by technology, because this mode can enhance peer interaction and group work.

Among the different active learning strategies, Cooperative Learning has found in the Internet and the World Wide Web the ideal technological support. In this scenario, we have implemented a web-based environment, endeavouring to reproduce within it the traditional teaching methodologies typical of cooperative learning. Herein we describe two experiments aiming to assess the quantity and quality of the interaction promoted by the system and how such factors as gender, background knowledge and role affect communication. We compared the communication and the learning gain achieved in the experimental group that worked with the system, named Geometriamo, with those achieved in the control group working in class with the teacher. The results demonstrate that the use of an environment mediating peer-to-peer collaboration can be highly beneficial, even in primary school age. A high number of messages were exchanged among all pupils and, notably, the highest learning gain was recorded in the less able students in the experimental group.

Keywords: Cooperative learning, Collaborative learning, CSCL, E-learning environment, Educational technology

Introduction

In advanced nations, computers and the WWW in particular are having a strong impact on education. These tools must clearly be regarded as versatile aids rather than as a replacement for face-to-face teaching methods. Nevertheless, the growing use of the Internet in learning environments has enabled new learning models to be created addressing specific learning domains, as well as more general educational goals.

In particular, considerable attention has been paid in recent years to collaborative learning supported by technology (Hiltz 1994), because this learning mode can enhance peer interaction and group work. Although in the past the effectiveness of collaborative learning was not widely accepted because academic excellence was defined by individual achievement, the area of research known as Computer-Supported Collaborative Learning (CSCL) has recently shown rapid growth (Johnson et al. 1998, Choen & Scardamalia, 1998, Hakkarainen et al. 1999, Hoadley & Linn 2000, Enyedy et al. 1997).

One of the aims of CSCL is to increase the quality of the learning/teaching process by engaging students and teachers in coordinated efforts to build new knowledge and solve problems together (Dillenbourg 1996). This approach offers a good medium for classroom discussions that can facilitate participation and social interaction among students, and between the teacher and students (Shellens & Valcke 2005). In the face-to-face discussions which normally arise in the traditional classroom during collaborative type learning, the teacher's role is fundamental and shifts from that of unique information source to that of communication facilitator (William & Peters 1997).

To obtain successful online learning, in both a collaborative and an individual learning situation, three types of interaction must be present, namely learner-content, learner-learner and learner-instructor (Moore 1993). The first type, learner-content, is strictly dependent on the construction and organisation of the material, a task which is traditionally carried out by the teacher. The other two forms of interaction have to do with communication processes in the strictest sense, and depend on the quality of the tools made available in the given CSCL environment.

Among the different active learning strategies, much attention has in recent years been paid to Cooperative Learning, that has found in the Internet and the World Wide Web the ideal technological support for setting up collaborative activities with no space-time restrictions. There is still some terminological confusion between the two concepts, although John Myers endeavoured to clarify this, by declaring: "The cooperative learning tradition tends to use quantitative methods which look at achievement: i.e., the product of learning. The collaborative tradition takes a more qualitative approach, analyzing student talk in response to a piece of literature or a primary source in history." (Myers 1991). Our approach addresses both aspects, analyzing both the quantitative learning gain and the qualitative communication engendered.

Naturally, synchronous and asynchronous tools are not enough to ensure effective communication between learners and teacher and the interaction needs to be encouraged by appropriate stimuli leading to positive exchanges of opinion and outlook on the problem to be solved. A web-based cooperative learning environment, therefore, must help to build up a communicative network and provide an environment where student groups of varying sizes can work together to achieve common learning goals (Johnson et al. 1999).

Vygotskij (Vygotskij 1978) appraised the psychological implications of cooperative learning and asserted that *human beings are products of their cultures*, thus people learn from interacting with others around them. According to an analogous approach to the one adopted for intelligent tutoring systems, featuring the introduction of Artificial Intelligence techniques and methods (Schank et al., 1993, Schank et al. 1995, Roselli 1995), in cooperative learning environments the role of communication facilitator can conveniently be assumed by a virtual tutor, that simulates the teacher's role in a traditional setting. Cooperation has been found to act as a catalyst for the development of particular problem-solving abilities, because learners are able to continue to use the reasoning techniques and strategies assimilated while working with their companions or the teacher, when they later have to solve similar problems alone (van der Meijen & Veenman 2005).

This is the theoretical framework within which our research work is inserted. We have implemented a web environment, endeavouring to reproduce within it the traditional teaching methodologies typical of cooperative learning. Our WWW Hypermedial Cooperative Environment, called *Geometriamo*, is addressed to pupils attending fifth-grade at the elementary school. The experiments we describe were conducted last year and one of the aims, whose results are illustrated herein, was to assess the quantity and quality of the interaction promoted by the system in pupils aged 10-11 years, and how factors such as gender, background knowledge and role can affect communication.

Theoretical Background

Considerable research has been devoted to the benefits of CSCL. In particular, CSCL environments are considered as satisfactory tools that can: facilitate task-oriented and reflective activity (Choen & Scardamalia, 1998; Hakkarainen et al. 1999, Wegerif, 2004, Gillies, 2004), encourage complex reasoning and deeper levels of argumentation (Hoadley & Linn 2000), support mathematical problem solving (Enyedy et al. 1997, Nason & Woodruff 2003), improve the use of conceptual models (Bell, 1997, Wegerif 2004) and increase students' cognitive and metacognitive understanding (Brown, et al. 1998, Cohen & Scardamalia 1998, Shellens & Valcke, 2005). A large number of studies comparing CSCL and non-CSCL environments (Lamon et al. 1996) in high school or university settings have demonstrated that CSCL can achieve better results in terms of student learning gain (Berge 2003, Charnistski et al. 2003, Veerman et al. 2001). Only few experiences have yet been reported in the primary school setting (Lipponen 2003, Anastasiades 2003, Tapola 2001, van der Meijen & Veenman 2005), but in these, too, the value of the combination of new educational technologies, computers and the WWW, integrated with a traditional learning pedagogical model such as cooperative learning, has been stressed.

However, although many studies of CSCL environments have demonstrated positive results as regards both individual and group learning, others have pointed out some limitations (Guzdial 1997, Guzdial & Turns 2000). Poor student participation has been recorded, measured in terms of the number of messages exchanged and the number of lines per message, while another side effect (Feldman et al. 1999) is that students have been found to

tend to indulge in discussion more as a form of social interaction than for true learning purposes. It is now recognised that in distance learning situations, characterised by geographic and physical isolation, new communication strategies need to be implemented, which were not required in face-to-face communication. Thus, the role of online tutor, be it virtual or human, must concentrate on fostering constructive, focused communication achieving a balance between learning of the domain and social exchange.

In any case, considerations of a purely quantitative type may not be a sufficient metric for the assessment of the contribution of CSCL to the quality of the interaction, let alone of the efficacy of the resulting learning. As has been shown (Lipponen 2003), other conclusions may be drawn and results obtained if in addition to quantitative assessment some qualitative factors are taken into account, focusing on gender, motivation, communication direction, etc.

In this context, the effectiveness of the computer as a support for group work, and its effect on social interaction, take on great importance. In CSCL environments, unlike in face-to-face discussion, communication occurs by means of text messages. Several researchers have recognized the strength of writing as a communication tool. Writing messages gives students the opportunity to reflect, to share their ideas and expertise (Collins et al. 1991), to become more aware of their knowledge and to ask and answer questions without any problem of time limits. All these factors encourage a deeper level of thinking in virtual communities.

From the research standpoint, the possibility of recording discussions conducted in cooperative work sessions is of fundamental importance, as a basis for conducting in-depth analysis of the quantity and quality of such communication and its effects on the overall learning process.

Cooperative Learning and the method STAD for setting up the CL

Already by the beginning of the 1990s, in the USA considerable debate had arisen as to the best way to reform teaching methods in the fields of math and science. Teachers propend for the choice of integrating the traditional face-to-face formula, in which students are provided with information to be memorized, with active learning activities, in which the students are given the opportunity to build on the knowledge gained.

Cooperative Learning is achieved by dividing the class up into small groups that work together to achieve the best group results by means of mutual assistance among the group members. All the members of the group must work on the task assigned by the teacher and each is aware that the success or failure of each individual will affect the results of the whole group (“your success benefits me and my success benefits you, in short we all sink or swim together here” (Johnson et al. 1999)). This fosters both a team spirit and a more questioning approach to learning. The learner-interaction variable is obviously the key to success or failure, on which all the other variables depend (motivation, cognitive processes, class organization, assessment, etc.).

There are many collaborative and cooperative learning methods, which also can be considered as group learning methods and used in both classroom-based and web-based environments. One of the methods adopted for achieving Cooperative Learning is Student Team Learning (STL) defined by Slavin (Slavin 1980, Slavin 1990). It is fundamentally centred around interaction in small groups but, above all, on individual responsibility and the provision of incentives and rewards to stimulate the group’s individual and collective commitment. STL is one approach featuring various cooperative techniques, including the Student Teams Achievement Divisions (STAD) by Slavin, that we have chosen to implement in *Geometriamo* because it is suited to teaching disciplines such as mathematics. The focal point of this teaching strategy is interaction among the members of small groups, during which the notion of individual responsibility is reinforced by the fact that it has a strong effect on the final group assessment (Zhao, 2002). This individual accountability motivates students to do a good job of peer tutoring and explaining concepts, as the only way for a team to succeed is if all the team members have mastered the information or skills being taught. The effects achieved with this method are not confined to the cognitive sphere but include fostering interpersonal relationship skills. The teacher, in this context, is seen more as a source, rather in the light of a guide and a sounding board, than as an authoritative figure, and studies conducted by psychologists have demonstrated that this has remarkable positive character-forming effects.

The STAD technique subdivides the learning/teaching process into different phases: explanation by the teacher of the topic to be studied; subdivision of the class into small heterogeneous groups; group work; individual assessment; correction of the tests and final grading.

Groups should consist of 4/5 students and must be heterogeneous, so that in each group the different levels (good, fair, sufficient, poor) are represented, as well as both sexes and different socio-cultural backgrounds. In the group work the students' task is to assimilate the concepts learnt during the lesson and help their companions to do so. This work is carried out in two phases: solution of a series of simple exercises supplied by the teacher to learn the concepts studied during the theoretical lesson, and then solution of a complex exercise: the latter is the main goal of the group work.

During the subsequent individual assessment tests the students may not help one another because each student must be aware that he or she is responsible for his/her own level of understanding. The individual assessment is transformed by the teacher into a group assessment by summing the individual progress marks. This system of progress assessment allows each student to contribute to the group if, and only if, he or she does his/her best and demonstrates a substantial improvement as the work develops.

In the design of our cooperative learning environment the various components needed to reproduce the model in a virtual classroom were defined.

Geometriamo, a www hypermedial cooperative environment

The idea of building Geometriamo grew out of our awareness that nowadays the Net is very much used in schools, where an increasing number of cooperative experiences have been set up involving several different nations (Olimpo & Trentin 1993). In fact, in advanced nations the schools are equipped with online laboratories that allow large-scale exchanges of experiences at all levels. To examine the needs of schools at different academic levels, we decided to build a hypermedial environment for cooperative learning, *Geometriamo*, that aims to bring in virtual contact pupils from different classes and schools as a means of fostering constructive exchanges of opinion.

In the design and development phases the pedagogical model determined the building of the other components, in order to achieve the ideal environment for cooperative learning according to the STAD. In addition, when implementing the domain, the teachers contributed actively by providing theoretical material and exercises, to ensure the typical content for the scholastic level addressed by Geometriamo, as well as the appropriate level of terminology.

The result was found to be a versatile tool combining the features of a tutorial system and a CSCL environment. In fact, in Geometriamo the domain is plane geometry, and the tutorial system is organized in hypermedial form, while the cooperative activity involved is that of assigning an exercise to each group, to be solved together reaching a unanimous conclusion.

In the tutorial part, the first knowledge transfer is in the form of "explanation by the teacher of the topic to be studied". Each topic is organized in pages on Theory and Examples (Fig. 1a and 1b). The former contain the explanations of the various geometric figures and the relative direct and inverse formulas; the latter pose model exercises (already solved) that teach the user the method for solving a geometric exercise.

The "group work" phase is set up by the cooperative environment. Each group can resort to a series of Simple Exercises (Fig. 1c) serving to apply what was explained in the Theory, and to the model exercises, as well as carrying out a series of Complex Exercises (Fig. 1d) that represent the task assigned. Each group must solve these by communicating among themselves and agreeing on the problem solving strategy to be used. At the end of the task the solution is communicated to the virtual tutor, which will provide positive feedback and reward, or suggest areas of further study.

The chance to work in a group and to interact, discussing a study topic or the solution of a task, was provided by a dedicated component allowing one-to-one and one-to-many communication. To exchange opinions, ask questions and make suggestions, the members of each group can use a messaging *notice board* that works like e-mail. Figure 2a shows the notice-board of the leader of Group 5. As can be noticed the group members have sent two requests for help. For each message the notice-board displays the sender, the receiver, the date and the number of responses received. Figure 2b shows the form for writing the message, the student has to fill the sender field (implemented using a drop-down menu), the subject and the text field. Moreover, in the left corner of both figures (2a and 2b) of the leader's notice-board there are three buttons that allow the leader to ask the tutor for help for a particular student, for the group that is having difficulty in cooperating or with a difficult exercise. In the right corner there is the virtual tutor's notice-board where all the answers sent by the tutor are

listed. In the example (Fig 2a) the virtual tutor invites the leader before asking for help for one of the group members, to try to discuss the problem better with him/her and to involve him/her more in the group discussion.

The figure displays four screenshots of a geometry software interface, each with a callout box explaining its content:

- 1a. Theory: Pentagons and Hexagons as regular polygons:** The screenshot shows the 'Poligoni Regolari' page. It explains that regular polygons have equal sides and angles. It details pentagons (5 sides, formed by 5 isosceles triangles with 72° angles) and hexagons (6 sides, formed by 6 equilateral triangles with 60° angles). A diagram shows a regular pentagon with side length $l = 20$ cm.
- 1b. Example: calculation of the perimeter of a pentagon:** The screenshot shows the 'Perimetro Del Pentagono' page. It presents a problem: 'Calcoliamo il P di un Pentagono regolare sapendo che: $l = 21$ cm'. The solution is shown as $P = l \times 5$, resulting in $P = 21 \times 5 = 105$ cm. A diagram of a regular pentagon with side length l is included.
- 1c. Simple Exercise: Calculate the perimeter of the Hexagon:** The screenshot shows the 'Perimetro Esagono (2)' page. It states 'Il Perimetro di un Esagono misura cm. 120.' and asks to 'Calcola la misura del Lato:'. A diagram shows a regular hexagon with side length l . Below the diagram is a form with 'Lato = cm' and buttons for 'Annulla Il Risultato' and 'Invia Il Risultato'.
- 1d. Complex Exercise: calculate the perimeter of GIGI:** The screenshot shows the 'Esercizio Complesso N° 1' page. It asks to 'Calcola il Perimetro P di Gigi composto dalle seguenti figure:'. The list includes: an octagon (testa) with side 12 cm, a pentagon (coppelle) with side half that of the octagon, two equilateral triangles (orecchie), a rectangle (gambe) with height 24 cm and width 6 cm, and two squares (piedi) with side 6 cm. A cartoon character 'GIGI' is shown with these geometric parts.

Figure 1: Some examples of pages (a)Theory, b) Example, c)Simple and d)Complex exercises)

As pointed out above, one of the advantages of text-based communication is that of keeping trace of the contributions by each member. All the messages sent and received are stored and can then be used as tools for assessment of the learning process, providing useful and detailed information on the dynamics of the interaction. For this reason, each member has to register. When a sufficient number of users have registered for the system to create heterogeneous cooperative groups, the collaboration activities can be started.

In addition, a leader must be individuated in each group, whose task is that of guiding and moderating the group work. In *Geometriamo* the leader interacts with the *Tutorial Component*, and asks for suggestions as to how to “promote” peer interaction. This tutorial component, implemented using Artificial Intelligence techniques, intervenes to stimulate collaborative activities, peer interaction and to suggest revision contents, as the Teacher does in the traditional collaborative classroom. This is possible because *Geometriamo* includes not only the typical components of an Intelligent Tutoring System (Knowledge Base, Student Module, Tutor Module and Student Interface) (Barr et al. 1982) but also a Group Modeling component (Group Module), that keeps track of the group history, providing the data for suitable intervention by the tutorial component.

Moreover, *Geometriamo* provides an assessment area that includes the “individual assessment” and “correction of the tests and final grading”. In this phase the pupil can take a final test that assesses not only individual improvement but also and above all, the group improvement, calculated as defined in the STAD. This places the emphasis on the group rather than the individual, in accordance with the cooperative philosophy.



Figure 2a: Example of leader's notice-board



Figure 2b: Writing messages in notice-board

Finally, there is an area devoted to the Teacher, who acts as supervisor, monitoring the work done in each group, in terms of exercises done, pages visited and assessment tests completed.

The Effectiveness of Geometriamo as a tool promoting communication

To assess the effectiveness of communication promoted by *Geometriamo* in a computer supported learning situation, two controlled experiments were conducted: a pilot study and a follow-up study.

Aim of the evaluations

The experiments were carried out on the one hand to assess the learning efficacy achieved in a distance cooperative learning environment and on the other, to see how successfully the electronic tool could mediate communication, and make interaction among the group members more active and productive.

Learning Effectiveness Questions

Both experiments aimed to answer the following questions:

1. Can children really improve their knowledge of geometric concepts by using the hypermedia?
2. Can the use of the cooperative learning system be as effective as cooperative learning in the classroom mediated by a teacher?
3. Can the use of the cooperative learning be as effective for less gifted students as for more gifted students?

Promoting Collaboration Questions

The follow-up study also aimed to probe the following aspects:

1. How many notes did each student send to his/her companions?
2. What is the relationship between communication and learners' ability?
3. How much does the factor of not knowing the other members of the group affect the interaction in a cooperative learning environment?
4. What relationship is there between gender and ability to stimulate communication among group members?

These questions were answered according to the method described below.

Samples

Two experiments were conducted:

- A first pilot study was carried out to see whether the environment or the content needed improvements. For this study only 24 pupils were selected.

- A follow-up study involved a larger sample: 152 pupils.

The pupils in both experiments were attending the fifth class at the primary school “XX Circolo Didattico E. De Amicis” in Bari. Learning using hypermedia was a new experience for all of them, but as we expected, some pupils were familiar with the use of PCs, primarily for playing games and for navigating on Internet to find information. In any case, the fact that some of them had no experience of computers was not a handicap because appropriate training in the use of the PC and the specific environment was given to all the participants.

The pupils firstly underwent an individual pre-test, developed in collaboration with the teachers, to assess their prior knowledge of geometry. For each test the teachers assigned an overall mark corresponding to the four levels (excellent, good, fair and poor).

The experimental designs

Both the experiments were designed using a mixed approach, with pre-test post-test as the within-subjects factor and the between-subjects factor. The children, 24 in the pilot study and 152 in the further investigation, were divided into two groups: the members of the **Experimental Group (EG)** used the *Geometriamo* hypermedia and the members of the **Control Group (CG)** carried out cooperative learning in class with the teacher.

The two main groups (EG and CG) were subdivided into cooperative subgroups, 6 in the pilot study and 19 in the follow-up study, each numbering 4 pupils. This number was defined on the basis of the STAD methodology, that prescribes small groups of 4/5 students, as well as convenience, as the system is currently able to manage four unit groups.

When forming the groups, care was taken to ensure homogeneity within and among groups both in the experimental and control groups, using both the marks obtained in the pre-test and the teacher’s overall assessment of each pupil for the previous year. Particular care was taken to match for sex, (2 males and 2 females per group), as this factor has a strong effect on *communication* among 10-11 year-old pupils.

In each group it was also necessary to appoint a leader to coordinate the group activities. The EG leaders could ask the virtual tutor for help in motivating the group cooperation, while the CG leaders could ask the teacher. The Experimental Group worked in the two laboratories available in the two school premises connected online to the server made available by our research lab, where the software was installed. The Control Group worked in the classroom, putting the desks of the group members together so that they could work and share materials, knowledge and skills.

In the follow-up study, because of the larger sample size, we were able to create more heterogeneous groups. As Figure 3 shows, in each group half of the subjects worked in groups of four including only classmates (denominated as EGClass and CGClass) and the other half in groups of four pupils from other classes participating in the experiment (denominated as EGMix and CGMix). This enabled closer simulation of on-line cooperative learning, in which participants do not know one another. This further subdivision allowed us to assess how much this factor of not knowing the other members of the group can affect the interaction in a cooperative learning environment.

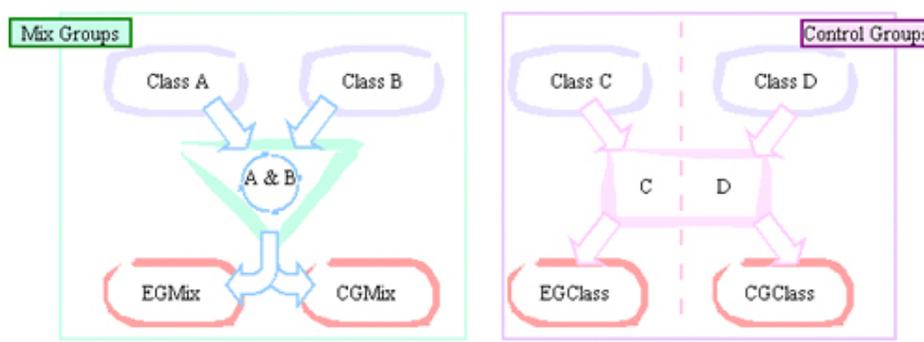


Figure 3: Distribution of the pupils in the EG and CG

Procedures

As stated above, the pupils firstly underwent an individual pre-test to assess their prior knowledge of geometry. Both experimentations consisted of three sessions, each one lasted an hour and a half, with a 2-day interval during the sessions. In the Theory session the teaching unit on the *perimeter of a regular polygon* was studied by the Experimental Group with the aid of Geometriamo and by the Control Group with the aid of the teacher. In the second session they worked on simple exercises, and in the third, they had to solve a complex exercise consisting of calculation of the perimeter of a compound figure (in Figure 4 the last two sessions are denominated Work Group sessions).

One week after the experiment, all the pupils were given a post-test. To try and control confounding variables related to the participants' history, no other geometric lessons were taught during the period of the experiment and the pupils were not given any homework on the topic.

Finally, comparison of the results obtained by each participant, in the pre-test and in the post-test, allowed us to evaluate not only the learning gain but also how much the peer to peer interaction had contributed to improve their knowledge.

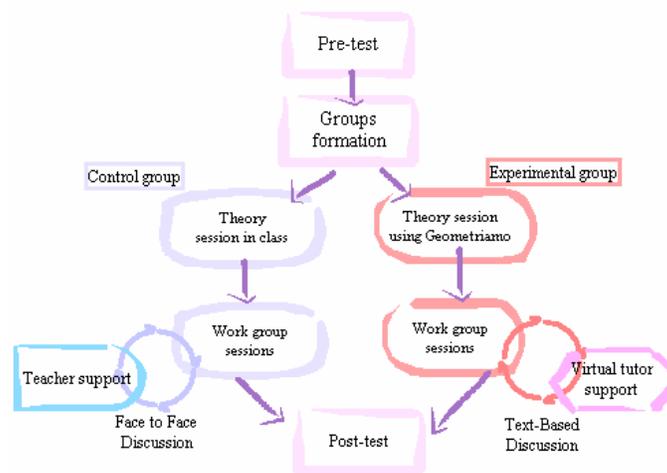


Figure 4: A graphic depiction of the experimental procedures

Results

Data analysis yielded the following answers to the research questions listed above.

Question 1. Can children really improve their knowledge of geometric concepts by using the hypermedia?

From an effectiveness point of view a first important result is shown in Figure 5 and Figure 6.

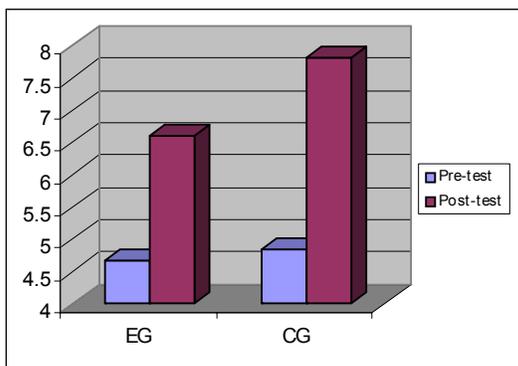


Figure 5: Average pre-test and post-test score in pilot study

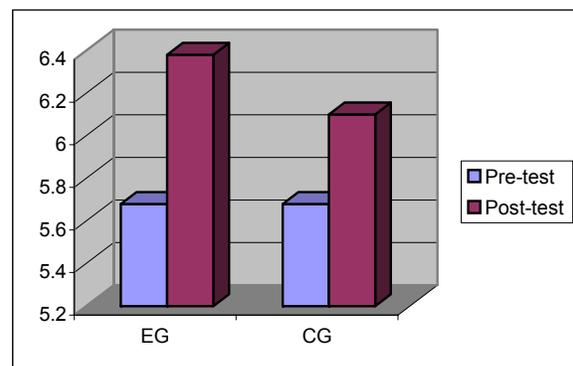


Figure 6: Average pre-test and post-test score in follow-up study

Moreover, Geometriamo provides an assessment area that includes the “individual assessment” and “correction of the tests and final grading”. In this phase the pupil can take a final test that assesses not only individual improvement but also and above all, the group improvement, calculated as defined in the STAD. This places the emphasis on the group rather than the individual, in accordance with the cooperative philosophy.

Question 2. Can the use of the cooperative learning system be as effective as cooperative learning in the classroom mediated by a teacher?

Table 1 and Table 2 report the t-test analysis, which was applied to the results of the post-test to test the difference between the performances of the experimental and control groups. The predetermined alpha level adopted for hypothesis testing was 0.05. The results confirmed the experimental hypothesis claiming an equal improvement over time in the two experimental conditions. This implies that all the children learned during the experiment and that this learning was almost identical in both groups. Therefore we can assert that no significant difference due to the mode of instruction was found between the two groups in either experiment.

Table 1 t-test analysis in pilot study

	N	Mean learning gain	Standard Deviation
EG	12	1.33	2.67
CG	12	1.17	1.59
Total Standard Deviation =			2.198
T(22) =			0.186
<i>t</i> =			1.717

Table 2. t-test analysis in follow-up study

	N	Mean learning gain	Standard Deviation
EG	76	0.66	2.30
CG	76	0.21	3.08
Total Standard Deviation =			2.722
T(150) =			1.007
<i>t</i> =			1.67

Question 3. Can the use of the cooperative learning be as effective for less gifted students as for more gifted students?

Scattering of data evinced an interesting finding reported in Figure 7, which shows that in the EG group pupils with a lower score in the pre-test had a higher learning gain. These results seem to confirm what previous research had pointed out: the use of the computer may promote better and freer communication among members of a group, reinforcing the inherent characteristics of the cooperative learning model. Very likely, the less directly personal confrontation occurring online encourages students with greater learning difficulties to voice their opinions and doubts, and this freer sounding-board effect benefits their overall understanding of the concepts under discussion.

Furthermore, the use of text-based communication gives students more opportunities for reflection and exploration of their own knowledge and this encourages deeper levels of thinking, a point which is particularly useful in less gifted students, who can thus realize what it is that they don’t know. The final result seems to be that of reducing the gap between less and more able students.

Question 4. How many notes did each pupil send to his/her companions?

The above results were confirmed by the number of messages exchanged during interaction with Geometriamo. The data collected in the Follow-up study demonstrate that the messaging component was amply used. In fact, during the three working sessions the 20 groups exchanged an average of 100 messages. Consistent use of the messaging function is confirmed by analysis of the individual messages sent (Figure 8), which showed that only 7 of 76 pupils sent less than 10 messages per session, while all the others had taken full advantage of the communication tool.

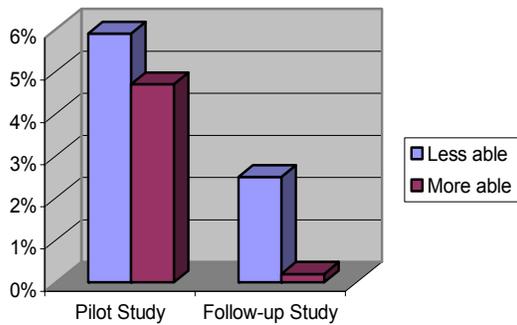


Figure 7. Learning gain of less gifted and more gifted pupils in Pilot study vs. Follow-up study

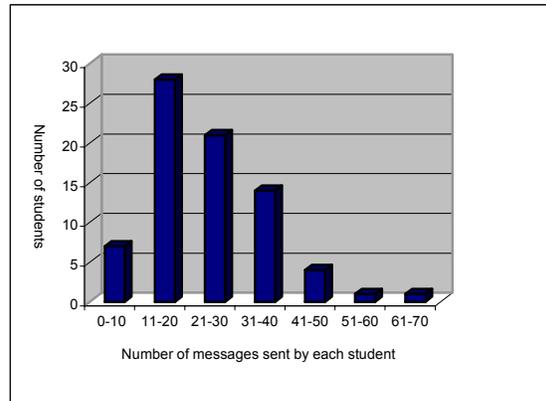


Figure 8: Number of messages sent per individual

Question 5. What is the relationship between communication and learners' ability?

Moreover, analysis of the number of messages exchanged according to the classification of the learner's ability (excellent, good, fair and poor) showed that as expected, the group leaders exchanged the highest number of messages because they had been made responsible for the promotion of communication, and more gifted pupils also communicated very extensively, as shown in Figure 9. On the face of it, and comparing these with the results discussed in Question 3, this would seem to imply that a greater level of interaction does not therefore result in a true learning gain. In fact, however, even if more gifted pupils sent more messages than less gifted ones, the learning gain was actually higher in the latter pupils. It would appear that even if they tended to experience the discussion rather more passively, less gifted students in any case felt themselves to be involved in the developing debate and were able to absorb the growing knowledge. In fact, the rare messages they sent tended to be requests for further explanation. This tendency was less marked in the EGClass than in the EGMix, showing that familiarity does, to a certain extent, smooth out such communication difficulties. In any case, even if messages were not directly addressed to them, the most gifted students took part in subsequent explanations, thanks to the stimulation provided by the Tutorial Component, that had the express task of promoting peer interaction and reviving it in case of difficulties.

In short, closer analysis shows that the high level of communication by the leaders is a demonstration of the achievement of another objective of the cooperative activity, that of encouraging more gifted students to help their less gifted peers.

Furthermore, it is interesting to observe that the tendency towards a higher number of messages exchanged among students in the EGClass than in the EGMix is reversed in the group of students classified as poor, reinforcing the concept that they are less overawed in an online and therefore more impersonal setting.

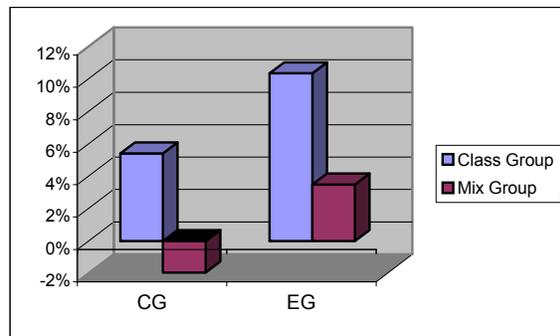
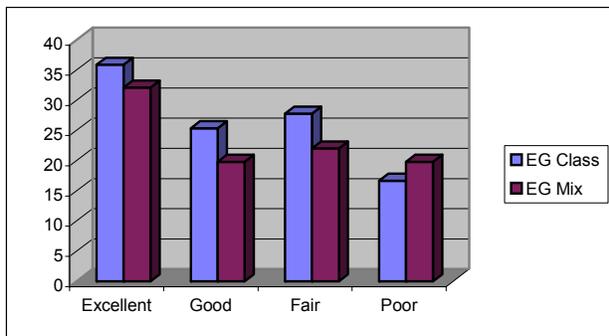


Figure 9: Number of messages exchanged per class of ability Figure 10 Learning gain in the class groups and mixed groups in CG and EG

Question 6. How much does the factor of not knowing the other members of the group affect the interaction in a cooperative learning environment?

Further analyses in this direction yielded particularly interesting results as shown in Figure 10, illustrating the comparison of the results obtained in the follow-up study, in the two groups (EG e CG) in their respective subdivisions (EGClass and CGClass versus EGMix and CGMix). As expected, even if all the groups showed an overall improvement in the EG, this was higher in the class groups than in the mixed classes groups, because children find it easier to work with their classmates. Instead, in the CG, although the class groups improved, the mixed class groups had negative results. One of the factors which could explain the results obtained is the communication medium used. In fact, while face-to-face communication inhibited pupils in the control group mixed classes, especially the shy ones, in the experimental group the mediation of the electronic system tended to overcome the psychological barriers created in mixed cooperative situations (a fear of asking for help, jealousy, pride in one's own abilities, etc,...).

Question 7. What relationship is there between gender and ability to stimulate communication among group members?

During group work sessions, the figure of the leader took on a fundamental importance in the task of stimulating communication by encouraging cooperation among his/her companions. Analysis of the messages sent by each leader revealed that female leaders appeared to be more able to involve the group and encourage cooperation among members than their male counterparts (see Figure 11).

However, this first impression was revised when the type of messages sent was considered in greater depth. Figure 12 compares the number of messages sent (quantity) with their type (quality). In this analysis we assessed how many of the messages sent by each group leader were directly related to the domain topic. The results were found to be approximately equal for male and female group leaders. In short, the difference in the results for overall communication seems to be due to a greater number of messages having been sent for relational purposes by female group leaders. Again, this result is not unexpected in the age group involved in our experimentation. In any case, overall, the results show that regardless of gender, the group leader is absolutely essential as the fulcrum around which cooperation can be built up and a miniature learning community created.



Figure 11 Correlation between gender and ability to stimulate communication in the group

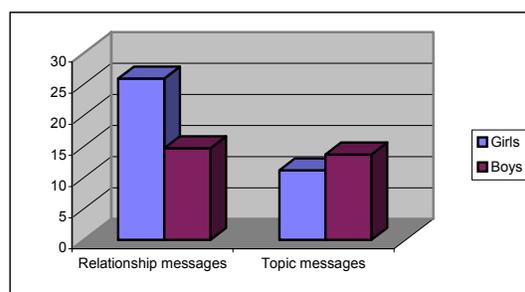


Figure 12. Ratio of relational versus topic-related messages sent by leader

Conclusions and future works

A multiplicity of different learning methods using the web as the communication tool, many of which are labelled as “non traditional”, are now available at all levels of education, and addressing all types of learners. They are now so widespread, and the quality of the learning promoted is so strongly supported by experimental evidence, that it is no longer justifiable to consider distance learning facilities purely as an alternative method for stimulating motivation in learners or for solving space-time problems. The ability to develop metacognitive skills fostered by CSCL environments is a very important aspect. The experiments conducted with our cooperative environment also aimed to address the synergic aspects of cooperative and collaborative learning; they demonstrate that a number of benefits can be gained with the use of an environment that mediates peer-to-peer communication even in primary school age. Collaboration skills are, after all, indispensable in our modern world, where a multidisciplinary approach is becoming the norm. After the first sense of diffidence toward the different communication tool had worn off, the experimental subjects appreciated the chances offered to talk to

pupils in other buildings and to share not only their knowledge and skills in the field of geometry but also the pleasure of building relationships with new, unknown peers.

Our experimental results confirm the value of our environment as a tool for stimulating collaboration in a cooperative learning situation. A high number of messages was sent in all EG groups. Comparison between the communication that took place in the EG and in the CG showed that although the efficacy results (Roselli 2003) demonstrated a learning gain in both groups, Computer-Mediated Communication was more successful than classroom communication for the purposes of fostering collaborative learning. Indeed, we found that the less directly personal confrontation occurring online seems to encourage students with greater learning difficulties to voice their opinions and doubts, and this freer sounding-board effect benefits their overall understanding of the concepts under discussion. Even if students classified in the lower aptitude groups tended to send less messages, and hence to experience the discussion rather more passively, in any case the less gifted students appeared to feel themselves involved in the developing debate and were able to absorb the growing knowledge. Another interesting aspect, namely analysis of the communication from the gender standpoint, was that while boys tended to send less messages than girls, their messages were more topic-related, while girls also sent many messages having a more relational purpose. Overall, the topic-related communication was comparable for the two genders.

All these results have encouraged us to extend research in this area. We are at present carrying out a reorganisation of the teaching content, modifying the environment to make it suitable for use with high school students. Further investigations will also be made of Geometriamo in the current version but in different contexts, for example by using it with children of different nationalities, to see whether the results obtained in the present experience are confirmed in other cultural milieus.

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