

Two empirical studies of computer-supported collaborative learning in science: methodological and affective implications.

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Abstract

In this paper the results and implications of two studies of computer-supported collaborative learning are presented and implications discussed. The first study was an experimental study in a British secondary school, while the second study followed a group of primary school children in a naturalistic context. Assessing learning situations is discussed with an emphasis on the affective factors. The differences between the products, the interactions and the outcomes of learning situations are discussed along with the research methodology. There is an emphasis on pre- and post-testing, naturalistic and experimental studies and time-based analyses.

Introduction

Many studies of computer-supported collaborative learning in schools have been conducted. Here we present the findings of two contrasting studies of computer-supported collaborative learning in science, one conducted in a secondary, one in a primary school and discuss their methodological implications. The paper begins with a short summary of the theoretical background followed by a discussions of the two studies.

Theoretical background

The aim of this research was to address the following questions:

1. What is the nature of students' collaborations with/around the computer?
2. How can we study and assess effective computer-supported collaborative learning?
3. How do students feel about using computers in a learning context?

A review of existing literature showed that there it is not clear that computer-supported collaborative learning is not necessarily beneficial relative to individual learning (O'Malley and Scanlon, 1990, Del Marie Rysavy and Sales, 1990) and also that very little attention has been paid to the affective aspects of computer-supported collaborative learning. Some

studies have found that collaborative learning has enhanced achievement, there have been studies in which learning is not enhanced, and recently, a study in which peer interaction inhibited learning. Successful collaboration was found by Blaye et al. (1991) who found on a planning task that children working as pairs were more likely to succeed than children working alone. In contrast, Messer et al. (1992) found that peer interaction did not facilitate learning on a balancing task, and in fact, inhibited learning.

Relatively little research has been carried out into what it is about working with the computer that motivates the students and how this affects the learning process and learning outcomes (Lens, 1992). Much of the research on computers in education has involved pre-testing and post-testing students' ability where investigators have focused on the change in a student's ability or knowledge using these tests, often making vague and anecdotal claims about affective outcomes. There has been very little research on how psychological factors, like motivation, are affected when students learn from the computer.

Ames (1984) has studied different learning situations from a motivational perspective, but she has not researched learning situations with a computer. Ames claims that children's evaluation of performance is a function of perceived success or failure. In a cooperative situation, group performance is salient, which is contrasted with an individual setting where the consistency of one's performance over time is important and in a competitive situation, social comparison information is important. As a consequence of this competitive structures promote egoistic or social comparative orientations, cooperative structures elicit moral orientations and individualistic structures evoke achievement-mastery orientations. Thus in cooperative settings there is a valuing of effort within the achievement context of cooperation. Thus the focus is directed on group performance over and above any individual characteristics.

The last ten years has seen a shift in the studies of computer-supported collaborative learning from

experimental methodologies within tightly constrained environments involving the use of pre- and post-tests to assess cognitive gain towards naturalistic studies in real contexts which include in-depth studies of the nature of the collaborations, focusing on a variety of features, including the nature of talk (Mercer, 1994a). Analysing the nature of collaborative interactions is one way of investigating computer-supported collaborative learning. Researchers often videotape interactions and these videotapes are normally analysed using categories of behaviours or talk that are considered important. The number of occurrences of these categories are summed and differences between pairs and within pairs reported. These results are sometimes correlated with the cognitive results derived from the study, and for example, conclusions drawn about the behaviours of successful pairs.

However, this type of approach ignores the temporal aspects of the collaborations. Several researchers have discussed developments which occur during the period of a collaboration. Salomon & Globerson (1989) discuss the development of interdependencies within a group over time, while Crook (1994) discusses the development of shared understanding over time. Mercer (1994b) discussed the historical and cumulative nature of talk and the way in which patterns of talk recur over time. However, none of these researchers have, so far, presented time-based representations of interactions and shown with empirical data, the ways in which these theoretical concepts develop over time. In this paper, the results of time-based analyses of collaborative interactions are discussed.

Summaries of two studies

Secondary School study

In this study, 11 individuals and 22 pairs of secondary school children aged between 13 and 14 years old used a chemistry database to fill in a worksheet about the Periodic Table. The task was defined by a worksheet consisting of 17 questions, 11 of these questions simply asked for information from the computer and 2 of the questions required the students to reason about the information they obtained from the computer. There were two different paired conditions, one in which the children shared a worksheet, the other in which each child had their own worksheet. Pre-, post- and delayed post-cognitive tests were carried out, and the students also completed pre- and post-test affective questionnaires. Their interactions were videotaped and a selection of the videotapes were analysed using an advanced computer-based video analysis tool.

Cognitive factors

The study found no clear cognitive benefit from working in a pair in terms of pre- to post- and pre- to delayed post-test gains. However, there was a significant advantage to working in a pair, particularly for those sharing a worksheet, with respect to on-task performance. This was reflected in significant differences in the amount of factual questions filled in correctly on the worksheets between individuals and pairs. This occurred because the pairs of students were accessing more information than individuals, as was shown by the videotape analysis. However, this was not reflected in the post-tests. We attribute this to the fact that the post-tests were individualised and the fact that the students in pairs worked collaboratively and this inhibited their achievements on the individualised post-tests.

Affective factors

Students said that getting on with each other was more important than getting the correct answers, their own success and their group success. There were no significant differences between their perceptions of their own and their group success. The use of the computer did not appear to increase their perceived interest or motivation towards chemistry, but increased their interest and motivation towards computers.

There were very few affective differences between the three different conditions. Surprisingly, there were no significant differences between the individuals and the students who worked in pairs. However, there were significant differences between those who shared a worksheet and those who had their own. Getting along with one another was significantly more important for those who shared a worksheet compared to those who had their own. When students are sharing a worksheet, in Slavin's (1983) terminology, there is a cooperative task structure, but no individual responsibility. It is not possible to ascertain whether the cooperative task structure or the lack of individual responsibility caused this increased emphasis on getting along with your partner. There was a significant decrease in the students' perceptions of how much they helped their peers for the students who did not share a worksheet but not for those who did. Ames' (1984) model describes collaboration as having a moral dimension, in which helping behaviour is important. Both these results show that in the condition where pairs shared a worksheet i.e. in which there was a form of collaborative task structure, the moral dimension is more important, and the students made more effort in terms of helping behaviour.

A selection of the videotapes recorded during the study were analysed using an advanced video analysis

program, Timelines¹. The videotapes were analysed in terms of talk and behaviour. Four categories of talk were used: topic, next, control and other. The behaviours that were used are: mouse use, typing, reading, writing, other, researcher present and looking at the Periodic Table. This type of analysis produced summary tables and time-based plots of the talk and behaviour. The analysis was applied to 10 pairs of students and five individuals. The analysis found inter-pair, intra-pair and inter-individual differences and the timelines and summaries from pairs who worked for more than one session, showed developments over time during the interactions (for an overview of this, see Issroff et. al., 1994). The analysis also showed differences between girl:girl, boy:boy and mixed gender pairs.

Primary School study

This consisted of a case study of a group of 9 and 10 year-old primary school children making a dynamic document about the water cycle, a task which extended over several days. A dynamic document incorporates pictures, sound and text and is like a slide show. The children were observed for about seven hours while creating the document on a computer. The group consisted of two girls and one boy. The children's notes were analysed, and parts of their interactions videotaped. The children and the teacher were interviewed after the document had been created. The children were asked about their collaboration and their knowledge of the water cycle. The teacher was asked about how he thought the collaboration had progressed.

The document produced is of a high standard. The children's draft notes provide a measure of their knowledge before they created the document and the interviews provide an in-depth description of their ideas after the interaction. Moar (1994) has described four phases that occur while creating this type of document (research, planning, construction and review) and in this naturalistic setting, the four phases are clearly intertwined, with some of the research phase being carried out towards the end of the study. The children split up the task as their interaction progressed, with one or two children working on the computer, while the other members of the group completed other work. Often, one child would be left to complete a particular slide on their own. A time-based representation of their interaction was constructed by hand, which clearly shows the ways in which the task was divided (for more details, see Issroff, 1995). While this is efficient, it led to some of the children having gaps in their knowledge,

which were revealed in the interviews. One of the children was particularly dominant and was also the computer expert which led to a lack of cooperation.

The progress of this group can be discussed in terms of Hoyles et al.'s (1992) characterisation of effective pupil-managed interactions. They discuss these groups as social systems and in a study, compared two groups and found that the group that produced high outcomes was '*characterised by the emergence of a synergy between structured pupil interdependence and pupil autonomy - that is, to a sharing of responsibility for successful task completion but a sharing in ways attainable by each and every pupil in the group*'. They discuss the influence of the task design and the role of the computer. They argue that when computer-based work is combined with other tasks, the group can structure a system of interdependence and the computer allows them to construct and develop their own ideas. For effective groupwork, there must be a minimum level of mutual respect and willingness to cooperate because the working patterns that develop are more dependent on interpersonal relationships than on the task. They suggest that as collaboration progresses, a pupil-teacher emerges and the pupil-teacher must have or acquire high status in the group and be a competent manager, monitor task progress, share knowledge, offer help and exhibit sensitivity to other group members. They also discuss the effects of interpersonal relations and in particular raise the possibility of undesirable outcomes when members work autonomously.

The present group can be interpreted within this framework. The task design was different from that used in the Hoyles et al. study and in this task there was the potential for autonomous work both away from and at the computer. The group fairly rapidly developed a working pattern in which the tasks were split and in cognitive terms, this may not have been beneficial. The boy made his own storyboard and the two girls did not understand some of the conceptual content. This may have hindered their cognitive progress.

One girl naturally took the pupil-teacher role. She seemed to have had the high status perception from the other girl before the interaction. At times, the dominant girl showed that she could be a competent manager and she did monitor task progress and shared her knowledge. However, although she did offer help, this was not always achieved in the most constructive manner and although she was sometimes sensitive towards the other children, she did not always act on her sensitivity. On the whole, she stifled the other children and often redid the work that they had done.

Damon (1984) suggests that the efficacy of peer interactions depends upon the extent to which children are able to negotiate both at the level of social

¹ Developed by Russell Owen, Ronald Baecker and Beverly Harrison at the University of Toronto for the Ontario Telepresence Project and the Institute for Robotics and Intelligent Systems.

dynamics and at the level of task organisation. This is true of the interaction described in this study, in which both the nature of the individuals and the nature of the task impacted on the nature of their collaboration.

The software used did not facilitate collaboration as indicated by the fact that the task was split. Much of the discussion of the topic occurred away from the computer, and most of the talk at the computer was concerned with aesthetic details, like colour and positioning of words. There were relatively few teaching interventions and these did not always have the consequences that the teacher intended. In order to promote effective collaboration, the software could be modified so that the children have less scope to change aesthetic features, for example by preventing the user from changing the colour of an object or letter more than once. This would help the children focus on the content, but arguably, advice for the teacher is more pertinent, but are not relevant to this paper.

Assessing learning situations

In the studies, an attempt was made to assess the productiveness of the learning situation. Much of the research in the area of collaborative computer-assisted learning focuses on the cognitive aspects of the interactions, largely in terms of pre- to post-test gains. Some studies have investigated delayed post-tests and on-task performance. However, relatively few studies have looked at the affective consequences of working collaboratively with a computer.

The Secondary school study looked at various aspects of the affective factors. Firstly, it investigated any changes in students' perceived interest and motivation, changes in the students' perceptions of themselves and their peers, the factors that students found important during the interaction, their perceived own and group success and their helping behaviour.

Perceived interest and motivation were examined in order to investigate claims about the motivating effects of working with others and of computers. The rationale was that students' opinions should be assessed in order to further investigate these claims. In the Secondary school study it was found that overall students' perceived motivation and interest towards the subject (chemistry) did not increase. However, their motivation and interest towards computers did increase as a result of completing the task. These results may have been as a consequence of the experimental nature of the study. This raises questions concerning the impact of the motivating effect of computers and how this carries through to the topic of the learning. The story is therefore complex and requires further investigation.

In the vein of Ames' cognitive-motivational theory of different learning situations, the studies investigated the factors that students found important

during the interaction. The students were asked how important it was that they got along with their peers and how important it was to get the correct answer. It was found that students thought getting along with their peers was more important than getting the correct answer. Individual success was more important than group success. This finding is inconsistent with Ames' theory and may be due to the experimental nature of the study and the nature of the task. From an analysis of the open-ended questions, it appears that students did not differentiate between their own success and the groups' success in filling in the worksheet.

The students' perceptions of their own and their groups' success was also investigated. There were no significant differences between the students' perceived own and group success. Again, this may be a reflection of the nature of the study, in that is an experimental, imposed collaboration.

In terms of helping behaviours, the students in the Secondary school study felt that they had helped their peers less than they had expected to, but their peers had helped them as much as they had expected them to.

The results of the Primary school study are of a different nature to those of the Secondary school study. The results are obtained from interviews with the children and are therefore affected by the fact that some of the children did not talk very much. It seems that one of the girls was very satisfied with what she had achieved and felt good about the way that they had worked together. The other girl also seemed pleased with what they had done, but this was not true for the boy, who said that he did not want to make another slide show with the girls. Also, one girl felt that she had helped the other children, and had received help herself, but in a different respect. The other felt that they had all helped one another, but the boy said that he had had help from the first girl but not from the second. It may be that the children's perceptions of what constitutes help are different.

Ames' cognitive-motivational theory of collaboration

The secondary school study provides partial support for Ames' cognitive-motivational theory. The primacy of social factors in cooperative situations was reflected in the students' ratings of the importance of getting along with one another. This was higher than their ratings of the importance of getting the correct answer. Ames also claims that group success is more important in collaborative situations than individual success. This was not found in this study.

There were no significant differences between the students' ratings of their own and their groups' success, which is probably a reflection of the experimental nature of the study. Additionally, the results of the open-ended questions about why the

students thought they were successful show that the students may not be able to differentiate between their own and their groups' success.

In terms of helping behaviour the students felt that they had helped their partners less than they had expected. In the Secondary school study, this was significant for the girls and those who had not shared a worksheet. The gender differences here may be attributed to the value which girls place on getting along with one another.

Products, outcomes and interactions

The distinctions between products, interactions and outcomes are important within the context of evaluating these types of learning situations. The product refers to the piece of work that is completed during the collaboration. In this sense, both the worksheet in the Secondary School study and the dynamic document produced in the Primary School study are the products of the interaction. The interaction refers to the communication between the students and between the students and the computer. The outcomes refer to any changes in the students' knowledge or feelings as a result of the interaction. In the Secondary school and Primary school studies, the products, interaction and the outcomes were examined. In the Secondary school study the product was the completed worksheets, the results of which have been referred to as a measure of the on-task performance. In the Primary school study the products were the children's notes and the final slide show.

One of the difficulties of evaluating a learning situation is combining evaluations of the products and the outcomes. It may be that students produce a very good document, but do not learn anything. Alternatively, the products of a learning situation could be evaluated as poor, but the students may improve on a pre- to post-test, and feel very motivated to work harder.

In the Secondary school study, the pairs achieved more in terms of on-task performance than the individuals, but did not achieve significantly more than the individuals on the post- and delayed post-tests. Although this does not allow one to unequivocally say that working in a pair is more beneficial than working individually, it is necessary to look at the on-task performance of a learning situation in conjunction with the outcomes. For the children in the Primary school study, the document that they produced was impressive and the other children in the class enjoyed watching it and said that it was clear and understandable. However, the outcomes of this interaction were not clearly beneficial to all three students, as exemplified by the boy's lack of knowledge in the post-test and the fact that the group had no future of the group as a viable partnership in his opinion.

Detailed interactions were investigated in a selection of the Secondary school students and in the

Primary school study. It is necessary to study the interactions if we wish to determine the factors that effect the products and the outcomes. The videotape analysis in the Secondary school study showed similarities and differences between individuals and pairs of students which were related to their pre- and post-test scores and their affective ratings. This provided descriptions of their interactions and facilitated some evaluations of the learning situation.

These results point to contradictions between the features which have traditionally been used to evaluate the effectiveness of computer-supported collaborative learning. In the Secondary school study, the on-task performance (the product) was not reflected in the pre- to post-test gains (the outcomes) while in the Primary school study, although the slide show (the product) was considered excellent, the children's knowledge was incomplete and one child was very unhappy (outcomes). These contradictions show that we should consider both products and outcomes in assessing computer-supported collaborative learning and that the effectiveness of an interaction cannot be strictly assessed by the measurable cognitive states of the individuals. Within an educational context, the criteria by which the effectiveness of the collaboration is assessed can be defined by the objectives of the collaboration (for example, to create a document rather than to expand the knowledge of the individuals involved), however, in research terms, we need to consider the product, the outcomes and the interaction in order to understand the nature of computer-supported collaborative learning.

Research methodology

Pre- and post-testing

The issues of pre- and post-testing are relevant to the Secondary school study. This showed the value of carrying out delayed post-test as well as immediate post-tests and points to the difficulty of drawing conclusions from investigating the interactions of the students who achieve the highest pre- to immediate post-test gains as these may not necessarily be the students who gained the most if a longer term perspective is taken.

Additionally, the study found that pre- to post- or delayed post- gains did not necessarily reflect the strength of on-task performance. Those who performed best on the worksheet were not the students who had the highest pre- to post-test gain. In particular, the pairs achieved more on the worksheet than the individuals and this was not reflected in the post-test scores. This may have been because the students had worked together and then filled in the post-tests individually and the fact that they had worked together may have had a detrimental effect on their individualised post-tests. Peer interaction was not beneficial in terms of individual learning

outcomes, but the students may have benefited in terms of collaborative activity.

Time-based analyses

Developments over time may be an important factor in the efficacy of collaborative interactions. This is an aspect of computer-supported collaborative learning which has not previously been investigated. There may be an optimal way of working together and this may develop over time - or conversely, students may begin by collaborating effectively but after some period of collaboration, this way of working may break down and the collaboration become inefficient. It is therefore important to look at the nature of the interactions over time.

Time-based analyses were used in both studies. In the Secondary school study, an advanced computer-based tool was used to investigate a selection of the interactions. This facilitated graphical representations of the students interactions over time. Consequently, patterns of talk and behaviour were discerned and these were interpreted relative to the products and outcomes of the collaborations.

In the Primary school study, Timelines was not used because it is not appropriate for analyses which involve relatively large units of time. Instead, a hand-made representation of the interaction was created and this provided a description of the interaction as well evidence of patterns within the interaction. For example, from the representation it is apparent that the collaboration broke down over time and the children stopped working with one another and split the task. It shows that the majority of the collaboration occurred while the children were recording the sound. It is also obvious exactly who was working with who, and the teacher interventions can be seen. It also shows the distribution of the four different types of activities associated with this type of interaction.

The time-based analyses clearly show the benefits of this type of analysis. These representations provide a way of describing the interactions and enable us to see patterns in the interactions. This type of analysis facilitates relating products, interactions and outcomes to one another.

Conclusion

This paper has provided an overview of two empirical studies on computer-supported collaborative learning. These have been discussed from various perspectives. In particular, they point to the necessity to take a wider view of assessing effective learning situations, which incorporates affective as well as cognitive factors and distinguishes between products, outcomes and interactions. The studies illustrate the value of time-based analyses, particularly when investigating collaborations which occur over more than one session.

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