The effect of group size in synchronous collaborative problem solving activities

Nikolaos Avouris, Meletis Margaritis, Vassilis Komis
University of Patras, Greece
N.Avouris@ee.upatras.gr, Margartis@ee.upatras.gr, komis@upatras.gr

Abstract: In reported studies of synchronous collaborative problem solving activities, so far, there are usually groups of two partners involved. In this paper, we focus on groups of larger sizes and study through an authentic educational activity the effect of group size on group performance and patterns of interaction. It has been found that it is possible to design learning activities with group sizes greater than two and that the group size affects performance and interaction. It was discovered that group skill balance in particular is an important aspect in this context. Therefore, the designer of such activities should design carefully the activity in order to get most benefits from the collaborative setting.

Introduction

It is believed that computer-supported collaboration can stimulate learning (Dillenbourg, (1996), Stahl, (2002)). Evaluation of new tools to support collaborative learning is an important process in this context, involving many phases and objectives. In this paper, we report on a field study involving evaluation of the effectiveness of a synchronous collaboration support software environment that allows peer interaction of collocated students who collaboratively build graphical representations of a semantic map. A layered evaluation approach has been devised and applied, which is briefly discussed in this section. The environment that was used in this study is *ModellingSpace (MS)* an open learning environment (Avouris et al. 2003), which permits modelling activities by students. This tool enables young students to build and explore models of various situations, allowing them to collaborate with other students and teachers in a local network or from a distance. Special emphasis has been put on support collaboration between students as well as tools assisting teachers facilitating and studying collaborative modelling activities. The evaluation methodological paradigm used is based on ethnographic (systemic) and discourse- analytic methods. Various parameters of collaborative problem solving scenarios have been studied in this process (e.g. Avouris et al. 2003, Komis et al. 2002). One of them that is reported here, concerning the size of the group of collaborating peers and the effect of this size on the learning achievements and group behaviour.

On the evaluation process

The field study is a part of the complex process of evaluating a groupware environment. This process involves lab testing, user testing and field studies which concern individual components of the environment and the integrated groupware itself. Lab testing is a preliminary phase, during which the users are given typical short tasks, out of context and their behaviour is monitored. Through these tests, the typical performance and task execution strategies are observed in order to establish if the offered functionality can support typical users in performing tasks. This preliminary phase reveals aspects of interaction with the tools. The mental model and the metaphor implemented by the design are tested in this phase. Cognitive processes at the level of the typical tasks are studied in detail in this kind of experiments. In addition, difficulties and misconceptions by typical users in relation to navigation, the design of the dialogue, affordance of handlers and commands, are identified.

Once the findings of the laboratory experiments are processed, and the software environment has been stable enough, in terms of its quality to be tested in authentic conditions, field studies have been performed which involve contextualization of the new software tools in various educational settings. In this case a large part of the architecture (client/server/supervisor tools) is tested and a number of aspects related to organisational and technological conditions that need to be met are evaluated together with the software performance. This is a particularly complex process, since there are many parameters that can influence the results of this study. For instance the design of the educational activity can affect the performance and the validity of the observed users behaviour, the role of the teachers and the technological competence of the support staff and so on. Questions like

"is the coordination mechanism implemented adequate for this age group? Are the supervisory tools provided effective for typical school environments? What is the optimal group size for typical collaborative model building activities?" can be tackled through evaluation studies of this nature and influence the design of the software. The ModellingSpace software itself supports these studies, since it contains monitoring, supervisory and analysis tools (Avouris et al. 2004), like those in fig 2. The interrelation of the evaluation objectives and evaluation approaches are shown in figure 1.

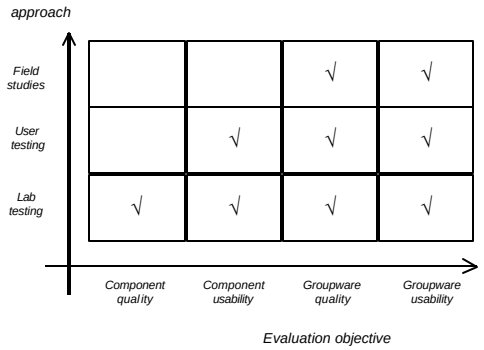

Figure 1. Overview of evaluation objectives and evaluation approaches

In this paper we describe a study of this nature. The study has been performed by the software designers and educational and research staff in the field. In the following section, we provide an overview of a field study that has been contacted in the process of usability evaluation of the ModellingSpace architecture, prototype and tools. The study reported here is focused on study of the group size and have as main objective to influence the design of the tools and the architecture. So, they have a formative character and for this reason are considered an integrated part of the iterative design process.

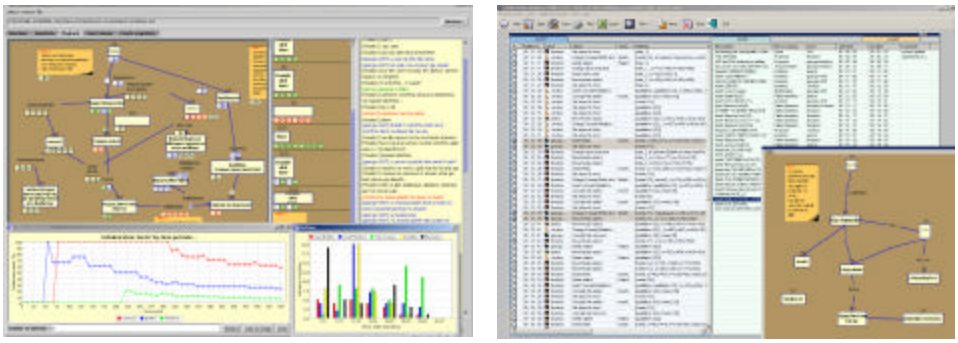

Figure 2. Tools and representations used in evaluation studies:
(a) playback of the activity and (b) annotation of the history logfile

Context of the Study

In contrary to most of other synchronous collaboration support tools (e.g. ModelsCreator, Fidas et al. 2004), the MS environment may be used by groups of students of size higher than two. This aspect had to be evaluated in the field. Questions like "What is the effect of the group size on problem solving performance" or "what is the effect of the group size on balance of students participation in problem solving" is studied in this case. The findings of this study could influence the design of the tools (group formation, chat) and the activities (moderated or non-moderated groups, support by the tutor) and lead to future development of the tools and the architecture.
This study was contacted in the frame of a University course where the collaboration support architecture of MS was used in the context of an authentic laboratory activity. Eighteen (18) students of the University of Patras, age of 22, during the laboratory of the undergraduate course on *Internet Technology* in the spring semester of 2003 were requested to build collaboratively, using a version of the ModellingSpace architecture, a concept map of an Internet service of their choice, out of those discussed in the class. They had one lab hour (around 45 min) available time to tackle the problem.

Six (6) groups of various sizes were build for this purpose. One (1) was made of four members, one (1) of two and four (4) groups of three members. The objective of this study was to investigate the effectiveness of the architecture and the provided tools to support groups of various sizes. The students were already familiar with the synchronous collaboration support environment and were soon engaged in task related activity.

As with previous studies with users of this age group, the students found the tools adequate and managed to produce satisfactory solutions to the problem. In particular, the group of 4 and the group of 2 presented a model of an e-commerce application (an electronic bookshop), while the groups of 3 students presented a peer to peer application (Kazaa), a model of email, a model of e-commerce process and one of a weather forecast service, respectively.

No major usability problems were presented during this study, while a number of shortcomings of the *establishment of a group session* process and *recovery of a session* after temporary failure of the network were identified. A typical example of the produced solutions is shown in figure 3.

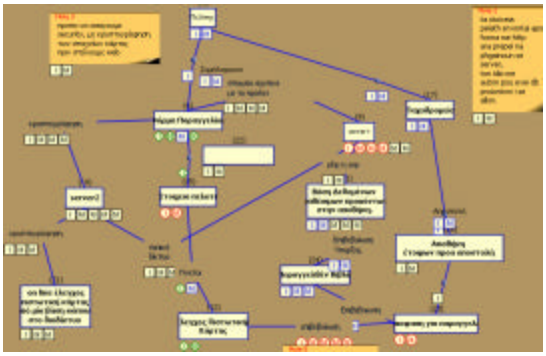

Figure 3. Group #1 Solution to the e-commerce application

The solution of group #1, made of four students is shown in figure 3 and the activity record for all six groups is shown in fig.4. The complexity of solution was high, as the produced model of an electronic bookshop was made of 27 components (fig.3). The solution of group #2 (made of two) was of medium complexity (9 concepts, 8 links). The pattern of activity in group #3 (fig.4) is similar to others, involving an initial chat phase, followed by a lot of activity and low communication and discussion at the end of the activity time. The activity pattern in group #4 is more uniform,, while the complexity of this solution is high (concepts=13, links=12). The pattern of activity in group #5 was more uniform, starting with chat, with action picking up quite later, while this group took more time than the rest (55 min). The complexity of this solution was low (concepts=6, links=9). The activity pattern in group #6 was one that involved more action earlier on, while a discussion took place quite late in the activity (during the 6th and 7th 5-min periods). The complexity of this solution was average (concepts=11, links=9).

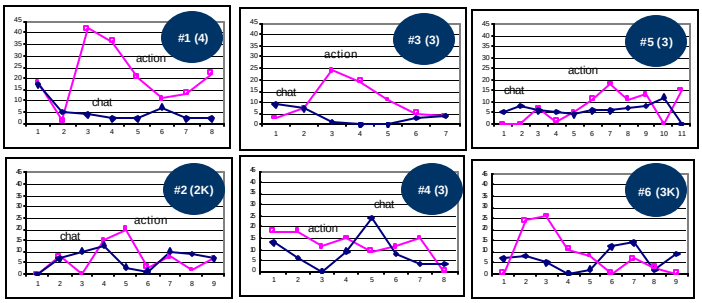

Figure 4. Activity evolution (chat and actions in the shared board) for the six groups of the study

Indices of group activity balance and skill balance.

Before embarking in this study we need to define some parameters of the collaboration activity. One essential parameter is the *Group Activity Balance* ***B***. This is expected to take values in the range 0..1 and take its max value for fully balanced groups and min for fully imbalanced ones. Considering as fully imbalanced group, one in which all the activity is performed by one partner, in this case ***B*** should be 0.

If we denote as c_i the contribution of the ith partner in the activity, measured as number of important actions in the

shared activity board plus number of non-trivial messages sent to the group, performed by this partner.
If we assume that N is the number of group members with N=2 then we can establish the total activity load as: $C=\sum_{i=1}^{N} c_i$ If we assume that $B_{max} = 1 \Rightarrow c_i = \frac{C}{N}$ for i=1,N (equal contribution of all partners) then we deduce $B_{max} = 1-k \frac{\sum_{i=1}^{N}\left|c_i - \frac{C}{N}\right|}{N}$ (1) where k is established such as $B_{min} = 0$. Assuming that B_{min} is the case for which there is a $c_j = C$ and $\forall i \neq j \; c_i = 0$. (all activity is monopolized by one partner).
By solving equation (1) for B_{min} we establish k= C $\frac{2(N-1)}{N^2}$, by substituting in (1) we obtain an equation that satisfies the original requirements and takes values between 0..1.

$$B = 1 - \frac{\sum_{i=1}^{N}\left|N \cdot c_i - C\right|}{2C \cdot (N-1)} \quad (2)$$

This is the group balance equation, where N is the number of group members C is the total activity load, measured as number of distinct events = total number of non-trivial actions in the activity board plus total number of non-trivial messages sent to the group by all partners.
In the same way, we can establish the balance index of the groups of their skill in relation to the subject matter. This is an index S which is measured in similar way as equation (2), expressed in terms of a measure of performance of each individual student in this subject matter s_i and S_{mean} the mean performance of the group. In our case, we used as measure of their skill, the students' performance in the final written exam in this subject, that took place just a few weeks after the study.

Analysis of study results and discussion

Using equ. (2) and the data collected from the activity of groups 1 to 6 in our study, we can establish their corresponding group balance index, see Table 1. In this Table we include for all six groups, the average group skill S_{mean} and the group skill balance S. The group skill balance had values between 0.88 and 0.96, while the activity balance took values between 0.21 (highly imbalanced group) to 0.89 (high balance).

Group ID	Group Size (**N**)	Group Balance (**B**)	Mean Group Skill S_{mean}	Group Skill Balance (**S**)
1	4	0,64	7,4	0,92
2	2	0,89	8,8	0,91
3	3	0,62	9,3	0,96
4	3	0,38	8,0	0,88
5	3	0,60	7,0	0,96
6	3	0,21	8,0	0,91

Table 1. Overview of the B, S, S_{mean} values for the 6 groups of students

Study of factors affecting the Balance of group activity
In this section, the effect of various factors on the degree of balance of activity is examined. Two factors are in particular studied. First the effect of the students skills balance, thus we try to establish if there is a correlation between *B* and *S* or *B= f(S)* and subsequently the effect of the group size on the observed group activity balance.
The relation between the two indices B,S can be deduced from Table 1, We measured the relationship between the B and S data sets. We determined positive Correlation = 0.323 between B and S. This means that in more balanced groups in terms of the skills of their members, the participation of the group members in the activity is more balanced. If we assume that the requirement is to achieve a balanced participation of the group members in the problem solving activity, we should take special care to create balanced groups of students, by allocating students of similar skills and abilities in the same group.
Subsequently we whish to establish the effect of the group size on the group activity balance B. Following a similar procedure, using the data of Table 1, we determine that there is a negative correlation between B and the size of the group. (correlation= -0.329). In other words, from this study it is determined that the higher the size of the group, the more imbalanced the participation of the partners in the activity becomes. An implication of this finding is that in

groups of large size, special care should be taken to encourage participation of all group members in the activity, if we wish to involve all students in the collaborative activity. In other words in larger groups, using such environments as MS, there is more chance to find lurkers who do not participate and therefore do not get the benefit of participation in the activity, so perhaps mediated collaborative activity should be sought in case of large size collaborative groups.

Study of factors affecting performance

A second aspect to be studied is the various aspects affecting the performance of the groups. We first defined the performance in terms of the solution produced by the 6 groups. The six solutions were all considered acceptable to this open problem. However it was soon discovered that there was a strong correlation between the complexity of the produced solution and its quality. The more complex the solution, the more the particular group had strived to study deeper the specific problem and produce a representation in the form of a concept map. In Table 2 we include the quality of solution parameter, as determined by the complexity of the produced solution (number of concepts and relations in the concept map), related to the studied parameters *B, S,* S_{mean}, *N*.

First, the relation between the group size N and the quality of solution is studied. In other words, do bigger groups produce better results or the overhead of communication, slows down the activity and produces lower quality results? In our case, it was found that the group size is a decisive factor for the quality of the solution (correlation=0.664). This finding needs to be further examined in groups of higher order. However the preliminary intuition has been that such an environment cannot be used effectively by very large numbers of users in a synchronous way. However the current study, has established that 3 to 4 students can also work fluently with the MS environment without any technological limitations. However, group sizes of over 4 members should also be thoroughly studied in order to establish if this finding holds for higher group sizes.

Group ID	Size N	*B*	S_{mean},	*S*	Quality (complexity)
1	4	0,64	7,4	0,92	27
2	2	0,89	8,8	0,91	17
3	3	0,62	9,3	0,96	24
4	3	0,38	8,0	0,88	25
5	3	0,60	7,0	0,96	15
6	3	0,21	8,0	0,91	20

Table 2 Quality of solution against group characteristics

Subsequently, we studied the other three parameters, *S, B,* S_{mean} in relation to the quality of the produced solutions. In this case, the effect found to be less strong. In particular the correlation factor with *S* = -0,316 with *B*= - 0,227 and with S_{mean}= 0,144. This finding means that the average skill of the group has no strong impact on the produced solution, while the balance of skills and balance of activity of the group has medium positive effect on the quality of the solution. In particular the effect of the skill balance and activity balance is negative to the quality, the more balanced the group in terms of the member's skills and activity, the lower quality solution is produced .

This confirms a finding of other studies that highly collaborative groups (i.e. groups in which the students have balanced activity) do not necessarily produce better results, or do not perform necessarily better in terms of academic achievement (Komis et al. 2002). A particular finding is that in relation to the last two indices, the group size seems to be more determining factor.

Study of the effect of group size on activity

In the last part of the study, we examine the effect of the group size on the quantity of the activity and on the balance between communication (chat) and action in the shared board. It was found that these two factors are highly related to the group size. In particular, it was found that the overall activity is positively correlated to the group size (correlation=0,702) and the chat to action ratio is strongly negatively correlated to the group size (correlation = -0,791). In other words, the larger the group the more activity is produced, something expected, as there are more actors to work in the shared space and talk to the group. What is more interesting is that the percentage of communication to action falls drastically with group size, i.e. the larger the group, the higher percentage of activity is contributed to action than to talk. This is an intriguing finding, which is probably attributed to the fact that the larger the group, the more difficult to address and convince everybody, thus the direct action, becoming more powerful means of expression. In contrary, in small groups and in particular in dyads, the partners do not feel

socially inhibited, so they feel more at ease to explain and discuss arising issues and adjust their speech to the specific partner. On the other hand in groups of large size there is always at least one out of many partners, willing to act in the common activity space, this is specially the case when no specific coordination protocol is imposed on the group, which was the case with our larger group.

Conclusions

In the frame of development of a collaborative learning environment, empirical research has to be carried out in the form of studies about the way the students and teachers appropriate the environment and make an effective use of it. One major question under investigation in this study was to establish the effect of group size and of the balance of participation of the students in the activity, using ModellingSpace. This is an important issue in such no moderated environments, since we need to understand the factors that inhibit participation of the students in the activity. In particular, in this study, the size of the group needed to be examined as one possible factor. From a study that involved six groups of varying size (two to four members each) it was found that in more balanced groups in terms of their members skills, the participation of the group members in the activity is more balanced. In addition, the higher the size of the group, the more imbalanced the participation of the partners in the activity becomes. The group size is a decisive factor for the quality of the solution. (correlation=0,664). The larger the group the more activity is produced. An additional observation has been that the percentage of communication to action falls drastically with group size. So the larger the group, the higher percentage of activity is contributed to action than talk.
Finally it was discovered that highly collaborative groups (i.e. groups in which the students have balanced activity) do not perform necessarily better in terms of academic achievement, an observation also made in other similar studies (Komis et al. 2002, Fidas et al. 2004).
The findings of this study may have a broader interest since they tackle fundamental issues of computer-supported collaborative problem solving, beyond the specific ModellingSpace architecture. An overall conclusion was that the group size seems to affect performance and patterns of interaction, while skill balance should be seriously considered when designing collaborative learning activities. However the findings of this study should be extended to a larger population of students and different group sizes, in order to claim general value of the observed patterns.

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