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Face-to-Face Collaborative Learning in Computer Science Classes*

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This study describes the application and effects of technological support for collaboration in a computer science course for engineering students. The technology in question is based on a wireless network of PDAs that implements a classroom dynamic to stimulate communication, discussion while arriving at agreement on questions put to students. The results obtained permit us to conclude that permanent use of Mobile Computer Supported Collaborative Learning (MCSCL) sessions improves the performance of students and their interest in the course. Furthermore, they demonstrated a greater ability to communicate both with their fellows and the professor, thus bettering their course results.

Keywords: face-to-face collaborative learning; assessment; computer science teaching

INTRODUCTION

ACCORDING TO KREIJNS [1], working in a CSCL environment has positive consequences both in terms of learning performance (the educational dimension) and social performance (the psychological/social dimension). Improvements in student satisfaction can also be expected.

This paper reports on a study in which technology was employed to support active learning in computer science teaching, exploiting the full potential of Computer Supported Collaborative Learning (CSCL) via wirelessly interconnected mobile devices to create a MCSCL (Mobile Computer Supported Collaborative Learning [2, 3]) environment. By 'active' here is meant the genuine participation of students in the learning process through activities involving discussion among their peers and problem solving [4, 5], as well as cooperative learning dynamics [6, 7]. In contrast to the traditional classroom in which students compete for achievement, MCSCL focuses on working together to achieve a common objective.

The implementation of MCSCL relies on a wireless network of PDA (personal digital assistant) devices designed to facilitate joint participation by members of a group in arriving at answers to assigned problems [8]. The application dynamic consists of the following steps: (a) formation of groups of three students; (b) solving each problem individually; (c) group members searching for agreement on a common answer; (d) evaluation by the system of the common answer; and (e) in case of an incorrect answer, returning to step (b). The application will reject answers that are wrong or not agreed upon by all group members. The professor receives feedback in real time through a grid displayed on his or her PDA indicating both the progress of each group and its rate of correct answers for each response. This allows him or her to intervene and assist a group that is experiencing difficulties with the activity.

Using MCSCL activities requires a certain amount of preparation on the part of the professor. To facilitate this, the system allows questions to be set up with their appropriate answers in a multiple-choice format. Before a class, a session is loaded into the system containing the selection of questions geared to that class's objectives.

The goal of the present study is to measure the effects of using mobile technology as a support for active learning in engineering courses. A combination of quantitative and qualitative methods was employed, including observation techniques and video analysis, questionnaires and analysis of students' academic performances.

CONSTRUCTIVISM IN COMPUTER SCIENCE

The currently dominant theory in education is constructivism, which holds that knowledge is not merely a copy of reality but rather a construction built upon structures that learners already possess.

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Thus, the theory sees learners as active constructors of knowledge, developing their understanding through observation, reflection, experimentation and interactions with their surrounding environment that continually confirm, challenge, or extend ongoing theories or beliefs [9]. On this view, the job of the professor is mainly to guide the student in this knowledge-construction process.

An important aspect of this process is its recursive nature in that it takes into account the particular history of the student in terms of memories and experiences. Thus, each learner constructs their own model of what they have learned. Inevitably, some of these models will not be viable. The professor's role is to guide the student in constructing viable models that are capable of interpreting new situations as they arise [10].

Constructivist ideas can be applied to the teaching of computer science with students who are able to create viable models of hardware/software [11]. The term 'viable/effective model', of key significance here, is taken to mean a cognitive structure that students can use to make viable constructions of knowledge based on sensorial experiences such as reading, listening or working with a computer.

As a final note, in [12] the authors observe that 'if the learning we attempt to provide has no basis in experience, it has little chance of modifying what the students already know', adding that teaching methods must be experiential to be effective.

CONSTRUCTIVISM IN THE CLASSROOM

Active learning

Active learning 'involves students in doing things and thinking about the things they are doing' [13]. The associated techniques have been shown to be successful in engineering education [4, 5, 14] not only in terms of student performance but also in their motivation to pursue the subject matter. This is complemented by research [15] showing that success in the labor market requires teamwork and communication skills. Indeed, the importance of developing these skills has been emphasized by the Accreditation Board for Engineering and Technology (ABET) in its current engineering program accreditation criteria.

An essential aspect of active learning is knowing what to ask. Its objectives may be summarized as knowledge recall, knowledge application (understanding in order to transfer) and motivation [16]. The use of active learning techniques in computer science courses has shown significant improvements in student performance [7].

Cooperative learning

In cooperative learning, the success of any student helps the others be successful in a team effort to accomplish a common objective, as opposed to the traditional classroom where students compete for success [17].

Cooperative work possesses a series of characteristics commonly cited in the literature that distinguishes it from group work [6, 7, 18]:

- Positive interdependence: each student must perceive that they need the others to complete the group tasks.
- Individual accountability: the quality and quantity of each group member's contribution must be evaluated and the results reported to the group and the individual.
- Face-to-face promotive interaction: each student depends on the other group members and so must help, encourage and support their efforts. The professor must also encourage the students to help each other.
- Social skills: to work effectively, students must develop and use social skills such as leadership, building trust, decision-making, communication and conflict management.
- Group processing: to improve group processing, students must periodically evaluate what they are doing well as a team and identify what changes are necessary in order to work more effectively in the future.

As part of a team, students learn to cooperate in solving engineering problems. They learn how to handle themselves in discussions on professional topics and argue and explain their views in scientific terms. The premise behind this is that presenting an argument is an effective way to learn.

In [7] a number of cooperative learning activities are cited that have been widely evaluated:

- Student teams-achievement divisions: in this activity, the professor provides study materials to the students, who are divided into heterogeneous study groups where they are motivated to work in pairs and come up with answers to the assigned questions. The students are evaluated individually and the groups with the highest evaluations receive the recognition of the professor.
- Jigsaw: students work on material that has been divided into sections, each group member studying a different section. Members of different groups who have studied the same section then join to discuss their section in 'expert groups'. Finally, they return to their original teams to teach their section to the other members.
- Group investigation: students work in small groups, asking questions, discussing and planning and developing projects. They then select subtopics within a single broad topic or subject area that are again divided up so that group members can carry out the necessary activities for preparing a group report. The reports are then presented to the rest of the class.

TECHNOLOGICAL SUPPORT IN THE CLASSROOM

To create an MCSCL activity, the professor's first task is to design a set of questions that motivate students to work on the subject matter, apply their knowledge, reinforce what they have learned and analyze how they are applying it. Each question will have a multiple-choice answer set that is stored in the teacher's mobile device before the class.

At the beginning of each class, students are required to randomly form groups of three members. By the end of the course they will have learned to work in a wide variety of configurations with students who have a good or weak mastery of the material, or who are friendly or unfriendly. Once in groups, each student's mobile device displays a question with alternative answers that must be solved individually. If the members of a given group opt for different answers, the system will not allow them to go on to the next question. It is at this point that collaboration between group members must emerge as they discuss, argue for their positions and come to an agreement so they can continue with the activity.

The diagram in Fig. 1 (taken from [8]) shows the sequence of steps in the collaborative algorithm students must follow to arrive at an acceptable answer for each question.

Figure 2 shows a group of students working together and discussing the questions put to them, creating an active and collaborative classroom situation that is facilitated by the MCSCL technology.

The MCSCL system also allows the professor to receive immediate feedback on how the class is doing. A grill on the master mobile device shows every question and each group's rate of correct answers on a color-coded scale, providing a visual display of the students' deficiencies or erroneous ideas regarding the course material. This enables the professor to take corrective action and, if necessary, use his or her device to momentarily suspend the activity of the entire class or a particular group while such action is taken. Figure 3 depicts a professor utilizing the information displayed on his device as he assists a group of students.

METHODOLOGY

The present study was conducted with students taking a required course in fundamentals of programming languages as part of a university-level computer engineering program. Forty students were divided into two sections, one being the experimental group and the other the control group. The latter was taught using only traditional teaching methods. Both sections were ensured equal access to study materials, made available on the university's Intranet.

The 16-week (one semester) course consisted of 32 classes, five of which were given using MCSCL before the first midterm exam and eight more using MCSCL between the midterm and final exams.

Student performance was measured on the basis of the midterm and final exam results. For purposes of the study only those students taking the course for the first time were included. Social and satisfaction characteristics were measured on a five-point Likert scale survey at the end of the semester (based on [19]) and the findings were supplemented with further information gathered using qualitative techniques that included observation methods, open questions and video analysis.

RESULTS

An analysis of the students' average marks for both tests (Table 1) revealed that experimental

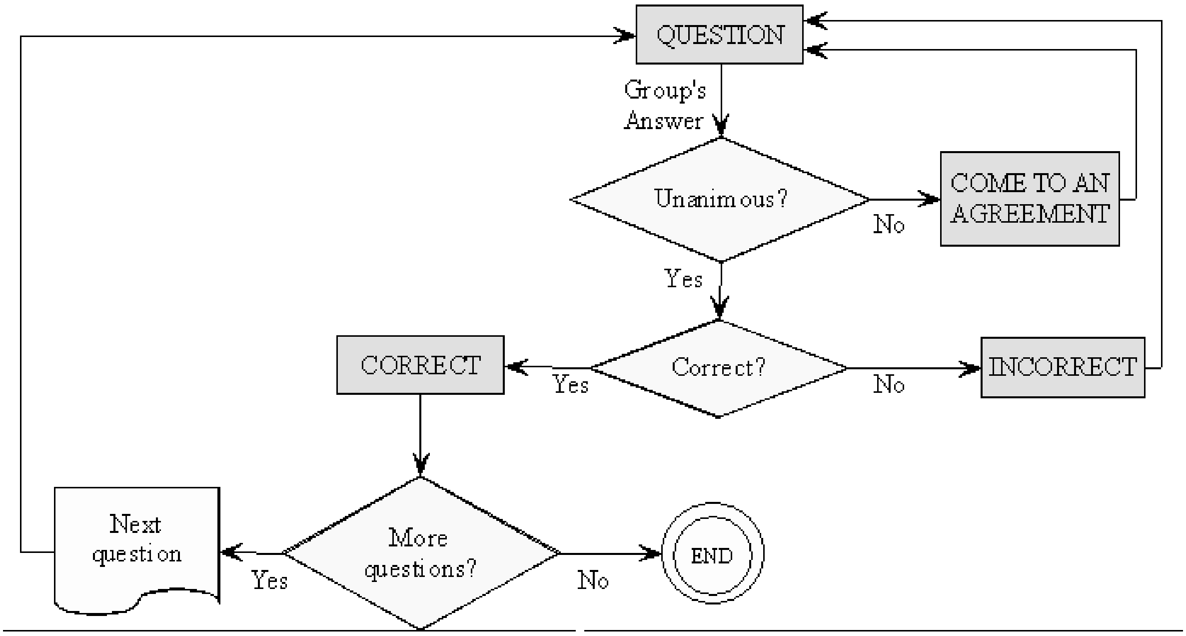

Fig. 1. Collaborative algorithm.

Fig. 2. Students working collaboratively with the support of MCSCL technology.

Fig. 3. Professor using MCSCL technology to support interaction with students.

group members performed better on both exams (evaluated on a scale of 1.0 to 7.0). The effect size (Cohen's *d*) of our intervention increased from a medium value on the first exam to a high value on the final exam [20]. Furthermore, a *t*-test found the difference in marks on the final exam to be statistically significant.

It is noteworthy that the control group's performance diminished considerably on the second exam, likely due to a decline in interest as the semester progressed. The effect was also reflected in indicators such as class attendance, for which the control group averaged 48.5% compared to the experimental group's 81.7% and course dropouts, which numbered four in the control group but none at all in the experimental group. The graphic in Fig. 4 shows the attendance's behavior through 32 classes in both groups.

Tables 2 and 3 show the results obtained from the qualitative analyses. The statistically significant differences detected by the questionnaire are displayed in Table 2. The response to question 5 indicates that students felt the technology helped improve their mastery of course content, thus reinforcing the global results on the course exams. The responses to questions 4, 6, 7, 10 and 21 reflect a higher level of confidence among students in the experimental group as regards the development of social skills, which is attributable to the use of the MCSCL tool (for the control group, the questions on the use of the technological tool referred to the university's Intranet functionalities). As for questions 13, 18, 19 and 20, the responses demonstrate that the experimental group was more satisfied with the course.

Table 3 contains the questions for which the responses showed no statistically significant differences. The results for questions 8 and 9 reveal no differences regarding access to the professor and to course resources. Question 17 found no difference on materials used in classes. The responses to questions 11 and 12 reflect the positive image enjoyed by both courses compared to others the students have taken, but no marked preference for the experimental course was indicated. Finally, the

Table 1. Analysis of students' exam results

Exam	Control		Experimental		Comparison			
	M	SD	M	SD	*t*	*df*	*p*	Cohen's *d*
Exam 1	4.5	0.857	5.0	1.048	1.4074	29.127	0.1699	0.52
Exam 2	3.4	1.361	5.1	1.537	3.5332	27.732	0.0015	1.18

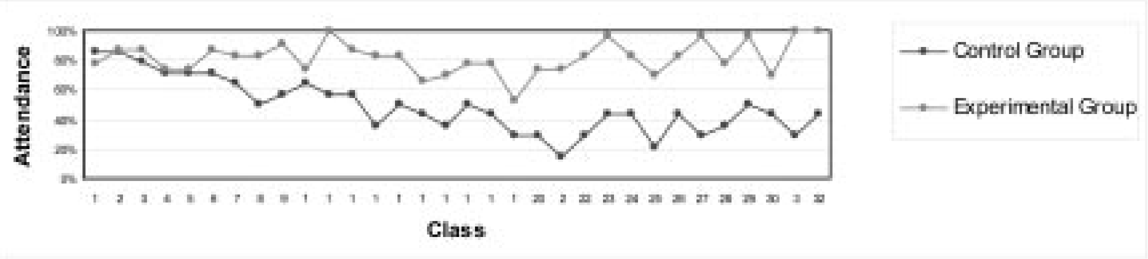

Fig. 4. Class attendance.

Table 2. Survey analysis (statistically significant results)

Response	Control		Experimental		Comparison			
	M	SD	M	SD	T	Df	*p*	Cohen's *d*
4. The technological tool increased my communication with the other students	2.2	1.3	4.4	0.8	5.0059	13.884	0.0002	2.26
5. The technological tool contributed significantly to my mastery of the course content	3.2	1.2	4.2	0.5	2.7587	12.479	0.0168	1.3
6. The technological tool enabled me to work effectively with other students	2.0	1.0	4.3	0.7	6.6724	16.584	0.0	2.83
7. I have had more communication with the professor thanks to the technological tool	2.6	1.4	3.7	0.8	2.32	14.29	0.0356	1.04
10. I have had more communication with the other students thanks to the technological tool	2.1	1.0	4.3	0.8	5.9488	16.958	0.0	2.50
13. I would take another course that used this technological tool	3.4	1.5	4.6	0.5	2.7163	11.276	0.0197	1.337
18. I would recommend this course to other students	2.9	1.1	4.0	0.7	2.8798	14.528	0.0118	1.292
19. It was easy to communicate with the other students in the course	2.4	1.3	3.9	0.8	3.708	14.348	0.0023	1.65
20. I would recommend courses using this technological tool to other students	3.3	1.2	4.6	0.5	3.4606	12.137	0.0046	1.65
21. It was easy to communicate with the professor, especially when using the technological tool	3.0	1.0	4.1	0.7	3.1968	16.386	0.0055	1.36

Table 3. Survey analysis (statistically insignificant results)

Response	Control		Experimental		Comparison			
	M	SD	M	SD	T	Df	*p*	Cohen's *d*
8. Access to the professor was increased through use of the technological tool	2.8	1.3	3.6	1.0	1.6414	16.868	0.1192	0.69
9. Access to resources was better in this course	4.2	0.8	4.1	0.6	–0.4829	17.935	0.635	–0.20
11. The course was more enjoyable than others I have taken	3.6	1.3	3.8	1.1	0.4485	17.982	0.6591	0.19
12. I felt more 'involved' in this course than in other courses	3.1	1.3	4.0	0.7	2.1254	13.887	0.0520	0.96
14. My class participation enabled me to learn more.	3.1	1.4	3.5	0.9	0.8869	14.825	0.3893	0.40
15. Taking this course increased the quality of my education	3.4	1.3	3.5	0.9	0.3066	16.339	0.763	0.13
16. It was easy to get help from the professor during class when I needed it	2.0	1.1	2.0	0.8	0.0	15.455	1.0	0.0
17. The classroom materials (textbooks, notes, exercises) were easy to understand	3.5	1.1	3.6	1.0	0.0826	18.37	0.935	0.03

answers given to question 15 also fail to display a better perception of the experimental course in terms of the quality of the educational process.

It should be noted here that in their responses to the open questions dealing with course characteristics, students in the control group referred only to achievements in content-related objectives whereas those in the experimental group also cited aspects related to social skills. This was evident in their response to question 10 ('I have had more communication with the other students') and testifies to the positive attitudes in the course (between students and the professor) and the encouragement of socializing among fellow students in the course.

CONCLUSIONS

In this study we show that MCSL technology opens new opportunities for introducing collaboration in the classroom and by doing so changing pedagogical practices. We observed that collaborative group activities promote student social interaction in the classroom and has positive effects on student motivation and learning.

The exam results tend to show that the regular use of MCSCL in active classes improves student performance and maintains their interest in the course. We think that this is more than a novelty effect considering that the experimental group maintained the class attendance through all the semester (Fig. 4). Deeper analysis of these aspects is a topic for future research. Of particular interest would be to measure the degree of correlation between increased use of MCSCL and improvements in performance, social skills and student satisfaction.

In general, the results on the social and motivational aspects demonstrate that students in the experimental course feel the MCSCL technology contributed to the improvement of communication with other students, as well as to the learning process and effective work activities during the course. Although no significant differences were found between the experimental and control group courses with respect to access to the professor and to course resources, students in the experimental group did feel they had better communication with the professor, especially when the MCSCL technology was being used.

We measured the effects of the used collaborative technology through a behavior analysis between the experimental and the control group. The experimental group sample size is small to statistically guarantee that the use of this technology can be generalized to others contexts with similar results. It is necessary to continue evaluating the use of MCSL in different areas and with a higher number of students in order to validate its use.

The questionnaire used in this study is based in [19], a study based in distance education. In a follow-up study it is necessary to reformulate these questions to avoid to be suggestive and to measure objectively the effects of technology.

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