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Face-to-face vs. Computer-mediated: Analysis of collaborative programming activities and outcomes

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***Abstract*—In this paper we present the analysis of a laboratory experiment designed to understand the effect of two communication environments, that is, face-to-face or computed-mediated, on group achievements when participants are involved in programming tasks, within an academic computer science course.**

Results show better students' performances in the computer-mediated setting, as stated by a statistically significant difference between the two approaches when considering the quality of the produced projects, in terms of the teacher's evaluation to pass the final exam. Our analysis shows that the integration of a collaborative instrument in a development environment helps students to achieve better results.

***Keywords*-collaborative learning; Web Services; computer-mediated communication**

I. Introduction

Programming is a typical activity that students usually conduct in perfect solitude, making it often boring and frustrating and, at the same time, involving an increment of the learning time and a degradation of the learning process [1].

Literature studies show that working in teams has a positive influence on the quality of performances [2] and on student achievements [3]. In contrast to the negative side effect of working in teams (i.e., free riding [4]), it is also assumed in the community that, when using computer-based collaborative learning, student participation is increased with respect to a similar face-to-face activity [5].

The growing interest in supporting collaborative learning is witnessed by several results available in literature, mainly aiming to improve students engagement and performance [1], [6], [7].

Differently from the above results, our goal is to evaluate the quality of the outcomes of computer-supported collaborative learning, rather than the engagement of students. A similar analysis has been presented by Erra et al. [8], as their evaluation of the quality of use case diagrams realized by groups of students in face-to-face setting vs. computer-supported setting.

Moreover, Beck and Chizhik [9] compared a group of computer science students, supported by a groupware, with a control group and found that, when considering all the majors analyzed in their study (Computer Science, Computer Engineering and so on), the difference between the two groups was statically significant (the scores were better for the experimental group).

Our study aims to investigate whether the computer-supported collaboration approach, through the use of collaborative instruments, can help students to improve programming skills and lead to a more organized and successful work compared to a collaborative face-to-face setting.

In particular, we want to verify if there are differences in the students' performances when they work by collaborating through face-to-face discussions and when they work leveraging on a collaborative environment and, in addition, if the usage of a collaborative tool to support structuring of work can improve the work quality and organization.

II. Method

For our study we recruited 20 participants (male 80%, with a median age of 22 years) among students of the third year of the Bachelor degree in Computer Science at the University of Salerno. Our sample consisted of students enrolled in a course entitled "Programmazione su Reti", with focus on Web Services programming. They had a good/excellent knowledge of Java programming (i.e., 85% of the students reported its good experience in programming with Java). The experiment was conducted at the ISIS Lab research laboratory at the same University. Participants were divided into five groups of four, with one freely elected as coordinator.

Our goal is to verify if there is a significant difference in the behavior of students when using the face-to-face approach (shortly $F2F$) or the computer-mediated approach (shortly CM) when collaboratively programming on specific projects, and specifically, when programming Web Services (by using Eclipse IDE with Apache Tomcat as Web Server and AXIS2 as SOAP Engine). At the same time, we want to verify which of the two approaches allows better results in terms of accuracy of the completed work, quality of the implemented code, minimum effort to complete the assigned projects. Finally, we want also to investigate if the computer-mediated scenario can help students to improve their learning performance.

We organized two types of activities with the same procedure in both of them. Specifically we asked students to work on both the design and the implementation of two Web

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Services-based projects: a *Bookstore* Web Service to manage consultation, reservation and requests for information of books online and a *Restaurant* Web Service to manage reservations and general information about food, specialities and prices. Both projects have the same complexity and refer to application domains on which the subject are not very familiar with.

The experiment was organized in two one-hour and half parts. The first part involved three of the five groups to work in a face-to-face setting and the remaining groups in the computer-mediated setting, then, in the second part we reversed the order of the tasks. This design is summarized in Table I.

Table I
EXPERIMENT DESIGN. ORGANIZATION OF GROUPS PER TASKS.

Groups	Task1	Task2
Group 1	*Bookstore*, $F2F$	*Restaurant*, CM
Group 2	*Bookstore*, $F2F$	*Restaurant*, CM
Group 3	*Bookstore*, CM	*Restaurant*, $F2F$
Group 4	*Bookstore*, CM	*Restaurant*, $F2F$
Group 5	*Bookstore*, $F2F$	*Restaurant*, CM

In both the settings each student was equipped with a personal PC and had the possibility to interact only with the students of the same group, through face-to-face communications (in the F2F setting) or by exploiting the functionalities of a collaborative tool, named Ec-CoFFEE[1] [10] (in the CM setting).

Ec-CoFFEE is a set of synchronous collaboration tools for Eclipse that is built on the top of the CoFFEE[2] (Collaborative Face-to-Face Educational Environment) framework [11], [12], developed within the LEAD project[3]. The CoFFEE Controller (launched by the teacher) and the CoFFEE Discussers (launched by students) are the applications developed to support the face-to-face collaboration in the classroom and they provide access to a set of collaborative tools: we focus on the "Threaded Discussion Tool" and the "Chat Tool". The Threaded Discussion Tool allows synchronous messaging between the students, structuring the contributions in threads to improve the organization of debates going beyond the temporal sequence of messages and highlighting the relationships among related arguments.

In order to carry out the experiment, we provided any student with an introductory presentation of the experiment and its main goal. We gave participants general information about Ec-CoFFEE, its goals and its main features. We also provided a detailed description of the projects on which work, remaining available for any further clarification, also during the experiment. As anticipated before, we installed the Ec-CoFFEE Plug-in on all computers and we provided students with the Chat Tool and the Threaded Discussion Tool which allowed us to define the structure of the projects, giving participants hints on how to organize the work.

At the end of the experiment, we asked students to spend other 15 minutes to fill in a post-experiment survey questionnaire. This questionnaire mainly aimed at getting the perceptions of students about assessment of interactions and learning, difficulties and effectiveness of both the approaches.

III. RESULTS AND DISCUSSIONS

In order to evaluate the students' attitudes towards a specific approach to work in a collaborative programming setting, that is, face-to-face or computed-mediated, we corrected the assigned projects by using the three following *metrics*. We first evaluated the correct design, organization and the correct execution of the two Web Services-based projects by assigning a score (from 1 to 10) to both the implementations in the two different tasks (Task1 and Task2 shown in Table I). Each project was composed of three different exercises with a different evaluation (score 3 for the first two and score 4 for the last one). The first two exercises exhibited a low complexity compared to the third one. In addition, the implementation of the third exercise required the implementation of parts of the first two. The results of this metric are shown in the "Develop Exec." columns of the Table II. Next, we analyzed the quality of the developed code ("Design Flaws" columns in the Table II) and, finally, the overall teacher evaluation in terms of the successful passing of the examination (for the "Programmazione su Reti" course), shown in the "Teacher Eval." columns of the Table II.

To evaluate the quality of the developed code we used the Eclipse Metrics plugin[4]. It allows to measure several metrics, whose definition and description are presented in [13]. For this metric, the lower the value, the better the result, contrary to what happens for the first and third metrics, for which is the exact opposite.

Table II
EVALUATION OF THE EXPERIMENTED SETTINGS ACCORDING TO THE DEFINED *metrics*.

	$F2F$			CM		
Groups	**Develop Exec.**	**Design Flaws**	**Teacher Eval.**	**Develop Exec.**	**Design Flaws**	**Teacher Eval.**
Group 1	4	6	23	4	6	24
Group 2	6	3	25	8	3	26
Group 3	7	3	24	9	1	28
Group 4	0	6	15	1	6	16
Group 5	3	6	17	4	6	20
Mean	4,0	4,8	20,8	5,2	4,4	22,8
Dev.St	2,7	1,6	4,5	3,3	2,3	4,8

[1] http://marketplace.eclipse.org/content/ec-coffee

[2] http://sourceforge.net/projects/coffee-soft/

[3] LEAD Project: Technology-enhanced learning and problem-solving discussions: Networked learning environments in the classroom, 6th Framework Programme Priority IST.

[4] http://sourceforge.net/projects/metrics/

As we can see from Table II, the groups "Group 2", "Group 3" and "Group 5" show improvements in all the analyzed metrics. Even with a slight difference in the first two metrics, the "Group 5" exhibits a final evaluation by the teacher of 20 (in the CM setting). This result allowed these students to pass the exam, whereas the corresponding evaluation in the $F2F$ setting was below the minimum threshold for admission (i.e., 18). We have also to emphasize that the teacher evaluation metric (compared to the first metric) also takes into account considerations about the developed code (i.e., indented code, significative variable names, output correctly formatted, indications about the input values and so on) and also used libraries and APIs (i.e., a more complex StAX parsing against the DOM parsing for XML documents).

The remaining two groups (i.e., "Group 1" and "Group 4") did not show any specific attitude toward one or the other approach. For these groups, the work done in both the assigned projects with the two analyzed approaches was fully comparable (and negatively valuated).

To verify if exists a significant difference in terms of quality of the work produced in collaboratively way using a $F2F$ or a CM approach when taking into account the evaluation of the teacher, statistical tests have been used. Specifically, we have applied the non-parametric Wilcoxon test [14]. This test revealed that a significant difference exists when considering the overall teacher evaluation of the produced Web Services (p-value = 0,039).

Another interesting result is about the relation between the quality of the realized project (shown in the "Develop Exec." column of the CM setting, Table II) and the use of the Threaded Discussion Tool during the experiment (in terms of the number of contributions per group). We found a strong relation (correlation coefficient r=0.96, R^2=0,9216), highlighting the usefulness of the Threaded Discussion Tool to organize the work and produce, therefore, better results.

The results of the survey questionnaire show that from the point of view of the social interactions, the $F2F$ approach highlights better results; conversely, from the point of view of the work organization and implementation, the students felt better performances in the CM setting. In general, the participants did not show any preference toward a specific setting, when queried about the usefulness of the experimented modalities of collaboration.

IV. Conclusion

In this paper we have presented a controlled experiment to analyze the performance of students when programming in an academic computer science course. In particular we have studied the improvements of the students results when they collaborate in both face-to-face conditions and in computer-mediated conditions.

Our study shows that the difference between the two communication approaches is statistically significant when considering the final teacher's evaluation of the produced Web Services-based projects. We have also inferred a positive correlation between the quality of the produced projects and the use of the Threaded Discussion Tool, as instrument to structure the discussions and the work to be done.

Finally, since the results reported in our study seem to be encouraging in the direction of best performance when students work in a collaborative computer-mediated setting, further studies need to be performed to examine the impact of the two approaches in a more wide setting, with a larger number of groups involved.

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