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The importance of interaction mechanisms in blended learning courses involving problem solving e-tivities

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***Abstract*—Blended learning is widely adopted by education agencies and organizations, as it is a flexible model in which face-to-face classroom practices are combined with computer-mediated activities. To overcome the limits of the loss of interaction between teacher and students and among students in distance learning, researchers proposed several solutions, conducting experiments in several teaching areas. Our interest is aimed at studying blended learning with a specific focus on those courses involving problem solving activities, through collaboration among students.**

Modern Learning Management Systems (LMS) allow to define virtual classrooms and offer various functionalities to support the class. At the same time, they are not designed to fully support all type of activities. Thus, they provide the possibility of integrating other more useful systems for more specific activities. A standard LMS has to be integrated using specific tools when problem solving activities are planned, to ensure effective collaboration among students. In this regard, there is no convergence towards a specific tool that can be used to carry out problem solving activities in collaboration.

This paper aims to propose a minimal set of requirements for interaction mechanisms to support problem solving activities in a collaborative environment, in order to obtain better quality artifacts. We also report the results of a three-month experimental course (12 weeks) entitled ”Project Management: a look ahead”, based on blended learning and problem solving activities. The minimal set of requirements for interaction mechanisms was implemented using GitHub, that is not a teaching software, but it is a global software development tool which has powerful communication mechanisms. The results show that the aid of the proposed minimal set of requirements for interaction mechanisms significantly improves the quality of artifacts when problem solving activities are carried out.

***Index Terms*—global software development, software engineering, quality, blended learning, collaborative learning, e-learning, problem solving activities, e-learning activities**

I. Introduction

Nowadays, blended learning model is widespread in many learning areas, because it provides the simultaneous presence of the teacher and students and it also allows students to complete the online activities, choosing the time and place in their own way [1]. Therefore, it is important to ensure adequate interaction mechanisms that allow the necessary collaboration among the actors of the teaching-learning process.

Universities adopted several blended learning models [2]. The quality of the e-learning systems based on these models is a crucial aspect, especially in the scope of the Bologna Process [3], an European project which aims to harmonize the architecture of the European education systems and, simultaneously, to focus attention on the needs and objectives of students. Therefore, it is important to assess the quality of these e-learning systems to achieve better results in the teaching-learning process.

Many research works defined blended learning models to improve and optimize learning outcomes, using different models depending on the teaching area [4]. In fact, efficiency and effectiveness of training are the key factors for education agency. To obtain effective results, it is necessary carefully to choose the tools that allow to increase the interaction, so that they are useful to carry out the planned activities. Our interest is aimed at investigating the effectiveness of a minimal set of requirements for interaction mechanisms as a learning facilitator in those courses that include problem solving activities, conducted in a collaborative way.

The planning of a blended learning course must take into account the needs of the students as a priority. In fact, LMSs do not contain all the necessary tools, because they are not designed to manage any possible scenario. To this aim, an LMS can be integrated with other tools. Therefore, the teacher must carefully evaluate the design of the course, so that students can effectively use tools to address specific issues. For these reasons, we believe it is important to define, in a formal and precise way, a minimal set of requirements for interaction mechanisms to help students to improve learning while addressing a problem solving activity that involves the participation of a groups of subjects. Indeed, in this type of activity, special mechanisms must support the participants in their teamwork. To this aim, it is important to underline that the provision of an appropriate or inappropriate interaction mechanisms can generate the success of a course, or its failure. Nowadays, the results obtained by the courses organized by a training institute contribute to determine its evaluation; thus, these results have repercussions on the organization itself.

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In this paper, we propose a minimal set of requirements for interaction mechanisms to support problem solving activities in a collaborative environment and report the results of an experiment to validate the influence of such mechanisms on the learning outcomes. We start from these considerations: *(i)* the contribution of a member must be immediately available and explained to the group; *(ii)* it is necessary that the system keeps track of the contribution of each member with its description; *(iii)* the system must memorize all version of artifacts, providing the possibility to restore a previous version; *(iv)* automatic notification mechanisms should be provided. These requirements are useful both for students and for teachers. We organized a computer science course designed on the blended learning model entitled "Project Management: a look ahead", lasting three months (12 weeks), in which we propose several problems to be solved in a collaborative environment. We implement our minimal set of requirements using GitHub [22], that is a global software development tool, and a traditional LMS, i.e., Moodle [23]. GitHub is not a teaching software, but it implements significant aspects of the required communication mechanisms. Therefore, we firstly trained the students on the features to be used. During the experiment, we monitored the activity of the students, keeping the activities under control through the logs of the system. We assessed the learning outcomes and experimental results are positive. Students appreciated this experience, as evidenced by a final evaluation questionnaire.

The paper structure is as follow. In section II we discuss background. In section III we indicate the basics of our proposal and we present our learning approach. In section IV we describe the experiment design, while section V shows the corresponding results. In section VI we discuss the results. Finally, section VII concludes the paper providing final remarks and indication for future work.

II. Related work

Blended learning models should be reviewed to take into account the progress made by technology and pedagogy. The basic idea is to choose a set of useful tools to recover the lost interaction, placed alongside the traditional Learning Management System. Therefore, a lot of experiments were conducted in this direction.

Many researchers used Web 2.0 tools to enhance collaboration between teacher and students and among students [5]–[8]. However, too many learning activities, as well as various learning materials and learning resources, are emerging in e-learning systems. So, it is difficult for individual learners to select proper activities for their particular situations/requirements, because there is no personalized service function [9]. Consequently, some researchers have designed Recommender Systems, which aim to provide personalized recommendations to face this problem [9], [10]. In this way, the system is able to profile the users. So, the system indicates the best method to carry out the e-tivities, depending on the user profile.

Salmon [11] refers to e-tivities as the e-learning activities designed to involve the student as an active part in the teaching-learning process, carrying out them by interacting with other students. With this word the author refers to a framework for active and interactive online learning. E-tivities can be used in many ways but they have some common features. E-tivities are: motivating, engaging and purposeful; based on interaction between learners/students/participants, mainly through written message contributions; designed and led by an e-moderator; asynchronous (they take place over time); cheap and easy to run - usually through online bulletin boards, forums or conferences. Key features of e-tivities include: a small piece of information, stimulus or challenge (the 'spark'); online activity, which includes individual participants posting a contribution; an interactive or participative element, such as responding to the postings of others; summary, feedback or critique from an e-moderator (the 'plenary'); all the instructions to take part are available in one online message (the 'invitation') [11]. In summary, research in this direction highlights the importance of the interaction mechanisms that underlie the activities to be performed.

A modern learning environment must provide e-tivities which, as defined by Salomon [11], are very similar to the problem solving activities. In fact, e-tivities are e-learning activities designed to involve the student as an active part in the teaching-learning process, carrying out them by interacting with other students.

In this work, we designed an experiment that involves some e-tivities [11] to be carry out in collaboration, according to the definition illustrated above. Therefore, from now on, we will refer more generally to problem solving e-tivities rather than problem solving activity. Furthermore, Hoic-Bozic *et al.* conducted an important experiment based on Recommender System and e-tivities [12], [13]. In their work, the system allows the use of the most appropriate tool to perform e-tivity, taking into account user preferences. In our proposal, similarly to the work of Hoic-Bozic *et al.* [13], we do not limit the user to specific tools, but we provide for the possibility for each user to choose the tool he prefers. For example, to manage documents he can use proprietary or open source software, to process images he can use the most preferred graphic software, as well as for all other types of files.

III. The proposed approach and research question

We observed several case studies that investigate the importance of problem solving activities in the e-learning context [14]–[19]. In fact, when a student is faced with a problem and has the opportunity to interact with other students, he is offered the opportunity to enrich their knowledge and skills to acquire competences to use them in a team, as required by the work context.

This type of activity is effective when the teacher and the students are in the same place at the same time; in this case, the teacher has planned lessons for acquisition of concepts and skills and then, under his supervision, the students can give their personal contribution to advance the

TABLE I
MINIMAL SET OF REQUIREMENTS FOR INTERACTION MECHANISMS TO CARRY OUT COLLABORATIVE PROBLEM SOLVING ACTIVITIES IN BLENDED LEARNING ENVIRONMENT.

Requirement	Description
R1	The teacher must be able to define one or more groups of students.
R2	The teacher must be able to define one or more ”milestones” that the groups must pursue; every milestone coincides with a problem solving activity or with a part of it.
R3	The start of a milestone must be automatically notified to all members of the group.
R4	Each milestone coincides with the production of one or more ”artifacts”, i.e., documents or other types of more specific files; students can create, modify or delete artifacts on their own or collaborating with other members of the group.
R5	The contribution of each student has to be clearly identifiable with respect to the contributions of the other members of the group.
R6	The system must allow to ”backtrack”, i.e., to go back to the previous version of the artifact.
R7	The achievement of the milestone causes an automatic notification to all members of the group.

state of the programmed problem solving activity. Sometimes a student can make a greater contribution than others, but work progresses through everyone’s efforts. This type of work is challenging for the students and the interaction between the members of the group is a fundamental aspect.

We analyzed several courses organized according to the blended learning model in our university, in which problem solving activities were proposed. They are often faced with standard communication mechanisms, such as the functionalities offered by the standard LMS platform, integrated by a repository such as Google Drive, email messages, and instant messaging services such as WhatsApp and Facebook. In this regard, we believe that these standard communication mechanisms are not a valid support neither to the students nor to the teacher. In fact, the students are not aware of the progress of the cooperative work and the teacher is not able to understand the contribution of a students compared to the others members of the group. Moreover, information is scattered in several repositories causing delays in their recovery and use.

Our interest is to study the mechanisms of interaction that can improve learning outcomes in a blended learning model with problem solving activities. In this context, the standard interaction mechanisms offered by an LMS are not sufficient to carry out these activities efficiently and effectively. To this aim, these systems have to be integrated with other more specific tools. We offer our contribution by defining a minimal set of requirements for interaction mechanisms to carry out problem solving e-tivities in a collaborative environment. We formed our idea from the analysis of the above reported case studies even if our approach is totally different, because we do not define the guidelines to follow and do not define the tools to be used, but we start with an entirely new point of view. We noticed that a student is motivated to offer his contribution when he realizes the exact contribution of the entire team. In practice, an interaction-competition mechanism is promoted. Consequently, we defined a minimal set of requirements, summarized in Table I, and, as we will see in the next section, we will implement a solution in which every requirement of this definition is described in terms of the functioning of the system and interaction mechanisms. Furthermore, in this paper we report the results of an experiment to validate the effectiveness of the proposed approach. In particular, we organized a computer science course designed on the blended learning model entitled ”Project Management: a look ahead”, lasting three months (12 weeks), in which some problem solving activities were planned. We chose to implement our minimal set of requirements using GitHub [22], that is a tool to support global software development, and a traditional LMS, i.e., Moodle [23]. GitHub provides excellent communication capabilities, including those of the minimal set of requirements we defined. Therefore, we trained our students on the interaction mechanisms to use and we monitored the activity of the students, keeping the class under control through the logs of the system.

It is worth to notice that GitHub was born and designed primarily to manage the source code. Instead, in our experimentation we use it to manage generic artifacts, such as documents, images and other files.

We formulated the following research question:

RQ: In a blended learning course, students using interaction mechanisms to carry out the problem solving e-tivities that implement the proposed minimal set of requirement achieve better learning outcomes related to the course objectives compared to the use of standard communication mechanisms.

IV. EXPERIMENTATION DESIGN

The course named ”Project Management: a look ahead” aims to achieve the theoretical knowledge and practical skills about the issues of managing a global software project, in which software engineers, programmers and other professional profiles located in different geographical areas of the world were involved. Specifically, the course was designed by including theoretical knowledge on issues related to the management of a global software project and practical skills on UML design, collaborative work and team management.

We designed specific e-tivities related to system design and cooperative programming, in order to give students the opportunity to carry out the e-tivities in collaboration with their peers, in groups of 2 or 3 students.

In our experiment, the participants were students of the Bachelor program in Computer Science, at the University of Molise enrolled in the 2015/2016 academic year. We divided the 28 participants in two groups of equal number of students, the control group and the experimental group.

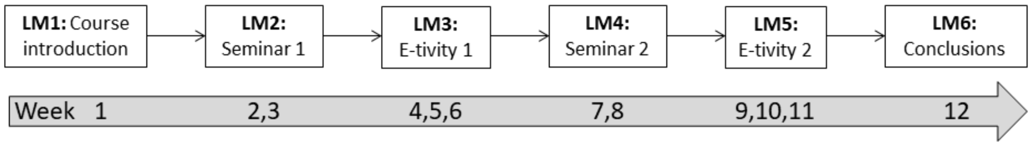

Fig. 1. Course design.

TABLE II
COURSE MODULES AND THEIR DURATION (WEEKS).

LM	Activity	Duration
LM1	Course Introduction: Project Management and Collaborative Work	1
LM2	Seminar 1: Unified Modeling Language: performed exercises	2
LM3	E-tivity 1: Collaborative UML design: problem solving activities	3
LM4	Seminar 2: Class Diagrams and implementation process: performed exercises	2
LM5	E-tivity 2: Collaborative code implementation: problem solving activities	3
LM6	Conclusions: Discussion of the experience	1

To ensure that there were no differences between the groups about previous knowledge and skills on design and programming, we asked students to fill in a pre-questionnaire to assess their background. We referred to pedagogical studies that suggest groups composed of students with similar ability and interest in the course topics [20]. The results highlight that there are no significant differences between the groups.

The course "Project Management: a look ahead" was designed to enrich knowledge and skills to acquire competences deriving from tackling the problem solving e-tivities, based on the interaction between the group members. It consisted of 6 learning modules (LM), whose timeline is shown in Figure 1. The description of the related activity and their duration (for a total of 12 weeks) is shown in Table II. The course give adequate time to the two problem solving e-tivities scheduled in the LM3 and LM5 modules (of which LM2 and LM4 modules respectively represent the prerequisites), on which the experimentation focuses.

The first problem solving e-tivity consists of exercises on UML design, while the second problem solving e-tivity proposes some exercises on code implementation. The control group carried out these problem solving e-tivities using the standard interaction mechanisms currently adopted in our University, such as those offered by the Moodle platform, integrated by a repository such as Google Drive, messages email, and instant messaging services such as WhatsApp and Facebook. On the other hand, the experimental group used Moodle to share the study material and GitHub [22] to carry out the problem solving e-tivities. In Table III we report the interaction mechanisms used to carry out the two problem solving e-tivities.

TABLE III
PLANNED PROBLEM SOLVING E-TIVITIES.

Group	LMs	Interaction mechanisms
A (control)	LM3, LM5	Standard: Moodle platform, Google Drive, emails, instant messaging services.
B (experimental)	LM3, LM5	An implementation of the proposed minimal set of requirements for interaction mechanisms, using Moodle and GitHub

In Table IV we report an implementation of our minimal set of requirements through GitHub. In particular, we describe how each requirement reflect the functioning of the system and how interaction mechanisms are used.

The artifacts produced by each student have been continuously monitored. The evaluation was carried out according to the individual contribution. Moreover, at the end of this experimentation student comments were collected. Finally, we highlight that volunteers were engaged in the experimentation, as they are more motivated and suited. Consequently, their interest has ensured the maximum participation and an respect for the modalities to carry out all the planned activities.

V. EXPERIMENTATION RESULTS

To address the research question presented in section III, we conducted a controlled experiment. We defined the following null hypothesis to assess the efficacy of an implementation of the proposed minimal set of requirements for interaction mechanisms:

H_0: *the use of the functionalities related to the minimal set of requirements for interaction mechanisms to carry out problem solving e-tivities does not significantly affect the learning outcomes related to the course objectives.*

The assessment takes into account all the activities carried out during the course. In particular, LM1 addressed the fundamental concepts concerning Project management and collaborative work; in this regard, the students downloaded the material from the platform, to study it. LM2 presented some exercises on the UML design to prepare students for the e-tivity provided by the LM3, to be carried out collaboratively in small groups of 2 or 3 members. Likewise, LM4 presented exercises performed on code implementation to prepare students for the e-tivity provided by the LM5, to be carried out in small groups. LM6 concludes the course with an experience evaluation questionnaire.

Participants carried out the two planned e-tivity, during the LM3 and LM5 modules. In particular, the interaction took place using the standard interaction tools in the control group,

TABLE IV
IMPLEMENTATION OF OUR MINIMAL SET OF REQUIREMENTS FOR INTERACTION MECHANISMS.

Requirement	Implementation
R1	The teacher can define one or more repositories, one for each group of students; for each repository, he can add the students of the group as collaborators.
R2	The teacher can create a repository for each defined milestone; then, he initialize each repository with a document detailing the activity to be carried out.
R3	The teacher can create an issue to briefly describe the activity to be carried out; then, he assigns this issue to all the members of the group, so each student receives the related notification.
R4	Each student can perform a fork to be able to offer his own contribution to an activity to be carried out with other students of his group; in this way, he obtain a copy of the shared repository, on which he can operate locally by git clone and git commit operations; then, he can use the pull request operation to send his contribution to the shared repository, including a description of his contribution; finally, a merge operation is necessary to make the changes visible to the whole group.
R5	The system stores the username and email of each contributor; furthermore, it preserves the descriptions of their contributions that they sent at the time of the pull request operations.
R6	The system stores all versions of artifacts and allows to restore one of them.
R7	When the activity has been completed, the teacher close the issue initially created and all the group members receive the corresponding notification.

while the experimental group used an implementation of the minimal set of requirements for interaction mechanisms.

We analyzed separately the results of descriptive statistical analysis for the e-tivity carried out during LM3 module ”Collaborative UML design” (see Table V) and for the e-tivity carried out during LM5 module ”Collaborative code implementation” (see Table VI). The values are related to the evaluation of the student artifacts, according to the 0-30 evaluation scale used.

TABLE V
RESULTS OF DESCRIPTIVE STATISTICAL ANALYSIS: E-TIVITY OF LM3.

	Control group (*)	Experimental group (*)
Minimum	18	22
Maximum	27	29
Mean	22.22	25.77
Standard deviation	3.49	3.63

(*) values are relative to the 0-30 evaluation scale

TABLE VI
RESULTS OF DESCRIPTIVE STATISTICAL ANALYSIS: E-TIVITY OF LM5.

	Control group (*)	Experimental group (*)
Minimum	18	23
Maximum	28	28
Mean	22.67	26.38
Standard deviation	3.87	2.22

(*) values are relative to the 0-30 evaluation scale

In both cases, the results achieved by the experimental group are, on average, higher than the control group.

We present the D'Agostino-Pearson normality test [21] in Table VII, showing a normal distribution in both cases.

Finally, we shows in Table VIII the results of F-test and Student or Welch t-test, depending on the result of the first test [21]. These results highlight a statistically significant difference between measures of central tendency for both e-tivities. In the case of first e-tivity results highlight $p<0.05$ significance level and for the second e-tivity results highlight $p<0.01$ significance level. Therefore, the null hypothesis H_0 can be rejected, to accept the alternative hypothesis. Consequently, we can conclude that the use of the functionalities related to the minimal set of requirements for interaction mechanisms significantly affect the learning outcomes.

VI. DISCUSSION OF THE RESULTS

Both the control and the experimental groups had the possibility to manage the artifacts in a shared way with the other group members, together with the possibility to manage the versioning of the artifacts themselves. The versioning provides the ability to store all versions of the project.

The fundamental difference is that the experimental group has used more effective communication mechanisms, according to our definition. In particular, we highlight the fact that the students of the control group offered their contribution using a shared repository, in which the differences between the versions only show the username, the date and the time of the modification. Instead, the students of the experimental group offered their contribution describing it, as for each upload it is necessary to insert a description to highlight the contribution of each one. In this way, from the point of view of teacher and students, the progress of the artifact and the individual contributions are clear and evident. In addition, the teacher has more than enough elements to carry out an individual assessment. Furthermore, experimental group had

TABLE VII
RESULTS OF D'AGOSTINO-PEARSON TEST (P-VALUE).

	Control group	Experim. group
E-tivity1: UML design	0.5693	0.1340
E-tivity2: Code implementation	0.5917	0.2332

TABLE VIII
RESULTS OF F-TEST AND STUDENT T-TEST (P-VALUE).

	F-test	Student t-test
E-tivity1: UML design	0.9403	0.0332 (<0.05)
E-tivity2: Code implementation	0.0807	0.0096 (<0.01)

the opportunity to experiment the implicit interaction mechanisms, when notification messages are automatically sent to team members, and the explicit interaction mechanisms, when team members send messages to each other [17], [18]. For example, implicit communication was tested when a milestone was started or completed, by automatic communication to all group members. Instead, explicit communication took place at any other time when a group member wanted to communicate with others.

In summary, these features lead the student, according to the definition of e-tivity, to become an active part of the teaching-learning process, collaborating with their peers. Practically, these features have triggered the competition mechanisms and, as a result, they achieved a significant improvement of learning outcomes in problem solving activities.

The final questionnaire related to the used interaction mechanisms highlighted the adequacy of the interaction mechanisms to assist the development of problem solving e-tivities, as well as having the opportunity to acquire practical skills that will be useful in a real working context. Furthermore, it highlighted the fact that it was necessary to understand well how GitHub works, which, beyond its potential, is quite complex, as it has much more functionalities than necessary.

VII. Conclusions and Future Work

In this paper we defined a minimal set of requirements for interaction mechanisms to be implemented to improve learning trough problem solving e-tivities in one of the most widespread teaching models, i.e., the blended learning model, in which the distance between the group members is a critical factor for carrying out this type of activity. Then, we formulated a research question to validate our approach.

We conducted an experimentation in which the experimental group had the opportunity to use an implementation of our definition of requirements. We presented and discussed a teaching experience "Project Management: a look ahead" about the management of a global software project. The course discusses the issues of the software projects involving designers, programmers and other professional profiles. The course included two problem solving e-tivities to carry out practical activities about design and programming in team. The problem solving e-tivities were designed to conduct students through the established intermediate objectives, without making them feel forced, in order to achieve the best learning outcomes.

The experimentation results confirm the effectiveness of our proposal. In fact, we achieved a significant improvement of learning outcomes in the experimental group compared to the control group. Furthermore, the comments of the students highlight a positive experience because they enriched their knowledge and skills with the acquisition of competences to use them in a team, as they will use them in the future work context. However, the final questionnaire results highlighted the need to improve the usability of the system, suggesting that it is useful to continue our research in this direction. Therefore, in the next future we intend to develop a specific software to implement the minimal set of requirements for interaction mechanisms, so that the strategy will be more easily applicable and usable in various contexts, in which collaborative problem solving activities can be usefully planned.

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