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# THE IMPORTANCE OF INTERACTION MECHANISMS IN COLLABORATIVE LEARNING

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# ABSTRACT

European policies indicate the necessary competences that citizens should have to adapt easily to changes in the working world.

Problem solving is one of the most important required competences and it is an important subject that interests us. In particular, we focus on the theme of collaboration, since the integration of different intelligences is more effective than individual contribution.

We defined a minimal set of requirements for interaction mechanisms to support problem solving activities to be carried out in collaboration. In particular, our interest aims to define those requirements that make it possible to distinguish the contributions of a member from those of the other members of the group.

In the teaching-learning context, our proposal mainly allows students to be more involved in contributing to the overall project, in order to achieve better results. Moreover, our work can also be useful in other contexts in which problem solving is strategic, as in the working world.

Our definition of minimal set of requirements for interaction mechanisms does not define the software that the teacher and the students will have to use, but it indicates the requirements that the software must meet, as they define the ways in which the teacher and the students will interact to carry out the planned problem solving activities.

For this reason, our definition, to be put into practice, requires choosing an existing software or develop one that meets our minimal set of requirements, after which it will be necessary to explain to the teacher and students the way in which it will be used to carry out the activities.

In this work we present a first experimentation of our definition of minimal set of requirements for interaction mechanisms. In this case we used an existing software, that is GitHub, which is not a software developed to carry out e-learning activities, but we chose it because it meets our minimal set of requirements. The results of the experimentation confirmed the effectiveness of our proposal, as well as highlighting aspects to improve the proposal.

Furthermore, we decided to design a software to directly implement our definition, which we called Problem Solving Support Environment (PSSE). Also in this case we performed an experimentation and the results obtained fully met the expectations.

Both experiments showed that the students of the experimental group obtained better results than those of the control group, but the second experimentation involved the design of a specific software to obtain a better result in terms of usability of the system, so that it is possible to use it in the most different contexts.

# INDEX

# 1.

# INTRODUCTION

The evolution in Europe towards more and more competences-based study programs derives essentially from the relevant European policy. The European reference framework of key competences for lifelong learning is an annex of a Recommendation of the European Parliament and of the Council of 18 December 2006.

The OCSE studies highlight that new graduates often lack those competences necessary to face the working world. In addition, those with specific professional competences are able to get a good salary and also have opportunities to make a career.

Problem solving is one of the most requested competences in the labour market. The process of the problem solving begins with the identification of the problem itself, continues with the listing of possible alternatives to address it, in order to identify the best one, based on appropriate evaluations.

Decision making is important for troubleshooting and many studies addressed this problem, defining problem solving models. In a nutshell, the process is divided into phases and instructions/techniques are provided to deal with them. In practice, problem solving is seen as a continuous cycle, rather than as a monolithic and finite process. It is clear that the way in which a problem is addressed is often decisive for the success of the related project.

Participants must have an agile and flexible mentality, opened to planning and activating processes in a different ways. Furthermore, participants should share their own strategies and processes, in order to help all the members to learn.

Adaptability is required for members of the group, who necessarily have cognitive differences; this factor allow to reach the solution of the problem more quickly.

Collaboration is important for problem solving, as the integration of different intelligences is more effective than the individual contribution.

Finally, communication is essential for problem solving, also considering that more and more employees choose to work remotely. Communication skills are essential to solve the problems of increasingly virtual teams.

Within this complex problem, our interest is focused precisely on this last factor, that is communication.

Many research studies defined guidelines to be followed in order to effectively tackle problem solving activities. Our work aims to support problem solving activities and our interest focuses on communication.

Our contribution to research aims to define a minimal set of requirements for interaction mechanisms to support problem solving activities to be carried out collaboratively. In particular, we pay special attention to those specific features that make it possible to distinguish one member's contributions from those of the other members of the group, with a dual purpose. The first aim is to make each member responsible to contribute to the overall work, while the second aim is to facilitate the work of the project manager who has to evaluate the members of the group.

According to this approach, our research work aims to offer a contribution that is useful both in teaching and in working context. In a teaching-learning context, our proposal allows both to involve the learners more in contributing to the overall project and to help the teacher during the assessment phase, i.e. when the contributions of each member of the group should be evaluated. Similarly, in the workplace, our proposal allows the project manager to be able to monitor the project, as well as to evaluate the individual contribution.

Our minimal set of requirements for interaction mechanisms does not define a specific software that the teacher and the students must use to carry out problem solving activities and does not even define the guidelines they must follow.

Instead, our minimal set defines the requirements that the software must meet in order to be labeled as conforming to our definition. The software to be used may already exist or may be developed specifically.

In this work, we designed two experimentations, the first that uses an existing software, i.e. GitHub, and the second that uses a platform that we specifically designed and developed to meet the requirements we defined, which we called Problem Solving Support Environment (PSSE).

In the first experimentation we used the GitHub software, which is not specifically designed for problem solving, as it is a software to support the development of distributed software. On the other hand, it meets the minimal set of requirements we defined. The results of this experimentation were positive, as the students of the experimental group obtained better scores than those in the control group. However, the final questionnaire allowed us to detect a certain complexity of the software features. In practice, this software allows to highlight the contribution of each student and the teacher was able to monitor the activities, but some software features have been judged more complex than necessary.

For this reason we decided to design and develop the Problem Solving Support Environment (PSSE) platform and to conduct a second experimentation. The results of this experimentation were positive, both from the point of view of the scores obtained by the students and from that of the potential use of this tool, which is easier to use in the most different contexts.

In this thesis we presents the hypotheses of this study and our contribution to research. Primarly, we address the importance of problem solving and the competences increasingly requested by the future work environment (chapter 2), to discuss the related strategies (chapter 3). Then, we address the e-learning and blended learning (chapter 4), to discuss computer-assisted collaborative environments (chapter 5) to support the carrying out of problem solving activities. Moreover, we present our definition concerning the minimal set of requirements for interaction mechanisms, together with a first implementation using existing tools, showing the results obtained by organizing a first experimental course (chapter 6). Furthermore, we show the platform we designed and developed to directly implement our definition, which we called Problem Solving Support Environment (PSSE) and we show its features (chapter 7) with the results obtained by organizing a second experimental course (chapter 8). Finally, the conclusions summarize the results obtained from this work (chapter 9).

# 2.

# THE IMPORTANCE OF PROBLEM SOLVING

## 2.1 Critical thinking and problem solving

Critical thinking means to be able to present new ideas, supporting them with adequate reasons to highlight their advantages and disadvantages. In school and in university, very often the teaching-learning process is conveyed in one way, that is on the assumption that there is no need to question the reasoning that the teacher presents to the students. However, this contrasts with the fact that the school and the university are just the preamble for access to the working world, in which problem solving is a key competency now essential.

## 2.2 Lifelong learning

Today we are talking more and more often about lifelong learning, with the awareness that an educational path is no longer sufficient to apply what we learned during the whole of working life, but we need to periodically update our training to adapt to changes of the working world, which is constantly evolving.

### 2.3 The method of study and work

Critical thinking is able to improve learning abilities; indeed, it allows to build and refine the method of study, which is effective and flexible to be then adapted to the working world.

In practice, critical thinking makes it possible to learn in a logic-based way, rather than on the acquisition of concepts in a mnemonic way. This way of thinking and adapting will become the working method of the individual.

### 2.4 The teaching-learning process

The traditional teaching process does not involve students' thinking. Instead, nowadays this concept is redefined and the teaching-learning process considers the need to design teaching giving great importance to the role of the student. He is a part and is involved in the process itself, not as a passive part, but as the protagonist of the process.

### 2.5 Critical thinking as a life experience

Critical thinking is not limited to the educational or working environment, but it can be applied in any context. The ability to think systematically also impacts on the way in which people make personal choices, searches for useful information for a specific purpose, online purchases, etc. In short, this ability is used daily in one's life experience. The aspect of everyday life is fundamental, especially if we consider that what is learned in the various fields of study is very often an end in itself and only sometimes is used in practice. Instead, critical thinking is transversal, used and refined every day.

## 2.6 Communication in the modern education sector

Universities and schools are increasingly attentive to the quality of the services they offer and are continuously working to improve themselves to be on the front line.

In the classrooms of schools and universities there are more and more tools designed to facilitate the learning process and to encourage sharing and involvement between teachers and students.

## 2.7 The role of technology

Technology is essential to prepare students for their future.

The introduction of computers and specific softwares to facilitate learning in the education sector allows students to use technology at school and at university, with the aim of encouraging their use in everyday life.

In practice, students are provided with all the tools necessary to face a constantly evolving society, in whitch technology is a prerequisite for all future professions.

The ways to communicate are multiplied. There are no longer only computers with broadband internet connection, but there are notebooks and tablets to encourage learning even outside the classroom or on the move, for example at home or on an educational visit or even in holiday.

With technology, the teaching-learning process has become interactive, in the sense that it has brought teachers and students closer together. However, an even more important effect is that it encourages new ways of teaching, so much so that new models of teaching are currently being tested.

An excellence educational institution cannot renounce new technologies, as it must always offer the best solutions to its students to help them to achieve their goals.

## 2.8 Internet of Things

The Internet of Things (IoT) is the network of physical devices, vehicles, home appliances and other elements incorporated with electronics, software, sensors, actuators and connectivity that allows them to connect and exchange data, creating opportunities for integration direct of the physical world in computer-based systems, with consequent improvements in efficiency, economic benefits and reduction of human efforts.

The IoT involves to extend Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, or any kind of physical devices and everyday objects that are traditionally stupid or not Internet-enabled. Integrated with technology, these devices can communicate and interact on the Internet and can be monitored and controlled remotely.

From this definition we understand how coding and programming languages, which today are the prerogatives of information and communication technology specialists, are among the skills that everyone must have in the near future.

Currently there are works to make coding and programming languages more easily usable by ordinary people. Some tools are beginning to be introduced in the field of education, making it possible to approach the IoT for the first time.

### 2.9 Coding

The inclusion of coding in education, from school to university, is a necessary step to prepare future generations.

Learning coding is essential in the same way that traditional languages and mathematics have been important to date.

Coding is the most important language of our generation and efforts are being made to introduce it into education. To date, there are many tools that allow young students to approach coding. Among them we mention Scratch of the Massachusetts Institute of Technology, although there are many others.

### 2.10 Programming

The tools that introduce students to the IoT and coding are based on an attractive graphic environment and are very far from the environments that are familiar to the experts. This is because they are designed for ordinary people who, otherwise, would not be willing to get closer.

In this way, everyone can learn how to program, starting with easy and engaging tutorials.

## 2.11 The creativity

Coding and programming stimulate creativity. The most modern tools also allow to create Apps for mobile phone, such as AppInventor of the Massachusetts Institute of Technology. It is the most intuitive tool among those available, as it involves the use of blocks like those of the puzzles.

There's nothing more creative than an App on own phone made by yourself for yourself.

## 2.12 Cloud computing: definition

Nowadays, cloud computing is widespread as a storage mechanism, a remote repository in which to store documents, images, videos, etc. In reality, cloud computing is much more than this.

The National Institute of Standards and Technology defines cloud computing as a model to enable, through the network, widespread, easy and on-demand access, to a shared and configurable set of processing resources (e.g., networks, servers, memory, applications and services) that can be acquired and released quickly and with minimal management effort or interaction with the service provider.

Therefore, cloud computing also means processing information (which is normally done by a computer's processor, a notebook, a tablet or a mobile phone).

As a result, the future sees programming integrated with the cloud environment.

### 2.13 Connectivity

At the base of new technology there is the concept of "always on" connectivity, which means that all our devices are permanently connected to the network, they are part of it and take advantage of all the features that it makes available.

That's why in the schools and universities, as well as in many other places, we have broadband and quality connectivity.

### 2.14 The future of learning

Videogames represent the way younger generations prefer to entertain themselves.

A new approach to education uses videogames in learning contexts to motivate and engage students. Among the most important aspects of this type of approach there is collaborative problem solving and the opportunity to level out what is learned from the group, especially to help the weakest.

The games have as their object the resolution of problems, or problem solving. This aspect makes video games an excellent tool for teaching, learning and evaluating. It has been shown that teaching through videogames enables students to engage and concentrate more and, in general, to improve their performance.

In this regard, higher level courses providing video-lessons and activities to carry out during the week have been tested. They give immediate feedback and provide that students level up or receive rewards, just like in a real videogame.

The future of our school system must include interactive activities, teamwork, competitions to excite and motivate students to maintain their commitment even after school hours. At the same time, students will be taught the valuable skills they need in the workplace.

### 2.15 Problem solving

The new generations must understand how the modern world works, because learning to use it now means being able to overcome the challenge of living a life in which the IoT is dominant.

Nowadays, the use of technology is an essential part of learning and will be increasingly important in the future.

This means that a radical change is required in the approach to technology of our educational system, as the future impact is considerable, both in terms of daily and working life.

Therefore, problem solving is important in education, as it is the basis of coding, programming, IoT, the cloud and, in short, the basis of the future need to know how to dominate the technology, in order to face the future working life.

In this regard, some education managers think of introducing a new subject of teaching in the various study courses, called problem solving.

Proceeding in this direction, we will be able to give students a completely new learning experience, in order to satisfy the right that every student has to acquire the skills necessary for his future.

We are also aware of the importance of considering problem solving as an entity in itself, as the development of logic can not be relegated to the good will of a small number of teachers in certain disciplines.

Furthermore, we are convinced that the key to success in learning lies in the active participation of students in creative activities concerning problems that can be solved in many ways (problem solving). These activities must be carried out in a cooperative manner and must be supported by innovative tools that can be used in the classroom and are available, even and above all, outside of it. These tools should enable team members to encourage cooperation and healthy competition, as well as to think independently and out of the box, to achieve original and effective solutions. The technology aims to create a learning environment suitable to support the planning and execution of collaborative activities, according to the most advanced research studies. Indicators should be provided on the progress of the activity in order to have constant feedback, with the aim of personalizing the students' learning experience, improving their performance and maximizing their chances of success.

All this in the awareness that the decision-making process is typical of the human and it cannot be replaced by a machine, which must limit itself to supporting it.

## 2.16 Research in the field of communication and problem solving

Research in education must take into account the role of technology.

Many research works focused on the aspect of communication, which affects not only the relationship between the teacher and the learners, but also the relationship between the students themselves, both in the classroom and on the move.

Communication is important to reduce stress, to improve efficiency and effectiveness.

Our work is also oriented in this direction and we focused on offering a contribution by studying the aspect of communication, during the carrying out of problem solving activities. These types of activities can be planned in schools and universities, but also and above all in the workplace.

In particular, the provision of an adequate communication tool makes it possible to keep alive the commitment after school/university time and start new interesting conversations on the topics learned.

# 3.

# PROBLEM SOLVING METHODS AND STRATEGIES

The methods and strategies of the problems described below come from an important research work on problem solving [1].

## 3.1 Direct facts

Direct facts represent a strategy of resolution concerning well-defined problems. The direct facts consist in seeking a path towards the solution based on known solutions. In general, the facts necessary for resolution are available in the memory of the person who has to solve the problem.

## 3.2 Heuristic

The heuristic-based problem solving strategy adopts the empirical rule or the possible solutions. Heuristics is a strategy based on experience with problems of the same type or similar problems. It is a type of problem solving approach that employs a method that, although supported by experience, does not guarantee the achievement of an optimal solution.

### 3.3 Analogy

The analogy is a problem-solving strategy based on the use or adaptation of an existing solution that solves similar or, in any case, very similar problems.

The concepts of analogy and similitude are based on the fact that some information is shared between the similar problem known and the problem to be solved.

Naturally, the ability to match relevant information between the known problem and the problem to be solved is required.

### 3.4 Hill climbing

The strategy called hill climbing consists of a certain number of steps towards the solution. Taking a step means performing an action that allows to get closer to the goal. In general, the starting situation is assessed, the final objective is focused and, depending on it, the best strategy to achieve the goal is determined.

### 3.5 Algorithmic deduction

Algorithmic deduction is a strategy to solve well-defined problems. The algorithmic deduction has a known and well-defined solution. Generally, a known series of operations must be performed to arrive at the solution.

## 3.6 Exhaustive research

Exhaustive research is a problem solving strategy based on the enumeration of all possible solutions. Every possible solution is examined and tested. This is a methodology that involves a very high complexity in computational terms. Consequently, in the cases in which the starting data are numerically high, this strategy is not applicable because the time taken to examine all the cases would be excessive. In these cases, an alternative strategy must be chosen.

## 3.7 Divide et impera

This problem solving strategy is based on the prior decomposition of the most complex problem into problems that are more easily solved. Naturally, the ability to decompose the original problem into sub-problems is fundamental.

This strategy consists of multiple steps. After having decomposed the original problem, it is necessary to work and solve the sub-problems and, finally, to compose the solution to the original problem starting from the solutions of the sub-problems.

This strategy derives from the human characteristic to be able to deal with simple problems more easily than complex problems.

## 3.8 Analysis and synthesis

The analysis and the synthesis of the problem is a strategy that involves first of all the understanding of the problem.

The formulation of a problem is often essential for its solution. For this reason, it is important to proceed with the clarification of complex problems, to reduce the problem to a known category.

Naturally, since this is a problem solving activity, the reference context must be taken into account.

When the problem has been appropriately reformulated it will be possible to proceed with the development of a specific representation of the problem, from which the solution to the problem will be derived.

# 4.

# E-LEARNING, BLENDED LEARNING, PROBLEM SOLVING

E-learning is the answer to the required change in the teaching-learning environment and is the way we look at the education of younger generations.

## 4.1 Democracy

Through e-learning, students can easily access education from all over the world, regardless of their geographical location, social class and spoken language.

E-learning also makes it possible to respond to the educational needs required by adults in their work environment. It allows people to learn at their own pace and time.

## 4.2 Potentiality

Of course, e-learning is more flexible than traditional learning, as the person interested in learning prefers to use a flexible tool.

Distance learning does not replace the traditional one, but integrates with it. This means that current education will not be supplanted, but will be integrated with new socialization tools, to work together even outside the classroom, in favor of accessibility, interactivity self-motivation and training effectiveness.

The learning experience technology mediated must also take into account the style of each individual and therefore must not tend to define a single path that is valid for everyone, but must be usable in a personalized way, tailored to the individual.

### 4.3 IT thinking and problem solving

Enhancing IT thinking and problem solving through coding and programming is essential to respond to the need to face the languages of the digital age, in which technology takes on an increasingly important role.

### 4.4 General purpose tools

Currently, teaching innovation sees the use of tools designed for the didactic field together with those general purpose tools, which are used to integrate functions not provided for in the first type of instruments.

Undoubtedly, among the general purpose tools there is the Google suite, which includes, in addition to the more classic GMail mailbox, also other Google Apps including Google Groups, Drive, Calendar, Keep and

Tasks, etc., which improve collaboration between people working in teams on a given project.

These are accompanied by messaging tools, such as Facebook and Whatsapp, which complete the framework.

### 4.5 Remote experimentation using general purpose tools

The Google suite has the advantage of being free for the education sector, it does not require expensive equipment or great skills. These features enable successful partnerships between schools and universities all over the world. With these simple tools, students are able to interact and work together.

Facebook groups dedicated to courses or subjects are one of the best ways for students to work together in the classroom or beyond. In addition, students also use WhatsApp groups to exchange information about the learning environment, both consciously and involuntarily.

The learning environment that allows students to use those tools with which they are already familiar makes possible to increase their confidence in the activities they have to carry out, as well as making them feel more comfortable even when we ask them to carry out new tasks. The relationship with the other members of the group will be easier, as they will be able to communicate in the same way they make a friendship.

Through the use of these tools, it will be easier to define clear tasks for each student who works on a project shared with his team. Furthermore, it will also be easier for their teacher to keep track of individual contributions.

The result will be a collaborative learning through teamwork, which is considered a fundamental ability to survive the continuous changes of the modern working world.

The teacher will take into due consideration the need to personalize the learning process of each individual student, respecting individual characteristics.

### 4.6 Cloud computing and data security

The world is moving rapidly towards full digitalization. Among the various technologies we must mention the one that is emerging more rapidly, that is cloud computing, through which contents are now accessible from anywhere, at any time. In this way we can continue to work outside the classroom or office, encouraging more and more the possibility of studying or working remotely.

The cloud allows to store and share data in a more secure way than the classic use of a portable hardware device, subject to problems of any kind such as the possibility of damage to the device. Furthermore, communication with the cloud takes place in an encrypted manner, ensuring the necessary privacy of documents. There are many questions about the security of data on the network, since the main cloud platforms do not guarantee that the data remain within national boundaries and, therefore, are protected by the laws known by the user on the matter. For this reason, it is recommended to encrypt files before uploading them to the cloud, especially when managing sensitive data, in order to have a higher level of security.

## 4.7 Project based learning

Through project-based learning, students carry out a particularly complex activity in order to fully understand the underlying concepts.

Students can work together on a group project, without the need for group members to be present in the same place, because they can work remotely.

The teacher or project leader can monitor the progress of the project and get immediate feedback, without the need to schedule on-site meetings for the purpose.

Among the advantages of this type of approach, there is the possibility of extending the project internationally, to simulate a model that is increasingly widespread in the globalized working environment.

This approach has the great advantage of stimulating active learning, involving each member of the group to contribute significantly by actively participating in achieving the objectives of the project. In this type of approach the role of the teacher is fundamental, as it guides the group of students by encouraging critical thinking and creativity.

This method helps students in the classroom and, at the same time, helps them build their future academic and professional success, as the skills they are learning can be applied to most areas of their future life. In this way they are led to analyze and improve their learning method.

## 4.8 Flexible learning

The learning methods must be effective and must also allow a high degree of flexibility. Each technological tool must allow the personalization of the learning path and the choice of the preferred tools, in order to take into account the preferences that each user has. For example, a student might prefer a software tool rather than another to manage documents, images, videos, etc. As a result, technology must not force students to proceed in the same way, but must provide for parallel and alternative paths to meet the needs of the most creative users.

## 4.9 Virtual, augmented and mixed reality

The virtual, augmented and mixed reality are the most innovative technologies that already improve our daily lives, but they will soon improve the learning experience in the classroom, as well as the quality of life.

This type of reality is not widespread, but it is becoming more and more. Just to mention one, some mobility support apps are able to reproduce on the display what is simultaneously taking up the camera, to add additional elements with respect to reality. For example, the display shows exactly what you see ahead of yourself, your car and a virtual car in front of your own, which you must follow to get to your destination.

In the educational field, teaching and research laboratories in virtual and augmented reality are already available for use at an educational level, even if they are not widespread.

Several research studies have already demonstrated the educational effectiveness of virtual laboratories and many others have already been launched to confirm the teaching effectiveness of learning laboratories that integrate virtual reality. It can be asserted that with these tools it is possible to live a remote experience that otherwise would not be possible, like seeing a dolphin and hearing ocean noises or visiting a company virtually to understand how the work is done inside.

### 4.10 Personalized learning

Personalized learning is a learning experience that considers the specific needs of each student and is recognized as an effective teaching method, as it facilitates the students' approach to the subject.

Thanks to cloud technology, the possibility of using video games and other tools to promote interactive learning methods, a teacher can provide for the personalization of educational paths.

Through personalized learning, there will be different paths of the various students to achieve the same goal, but in the end the whole class will reach the same level of knowledge, satisfying preferences and enhancing talents.

## 4.11 Bring your own device (BYOD)

The first way to personalize learning is to integrate the technologies that students already have, for example with the use of their tablets or smartphones.

In this way, a privileged communication channel is created between the teacher and each student, as well as between the students themselves, allowing everyone to interact even outside school hours.

Group projects are another way to design personalized learning. The teacher must understand the strengths and weaknesses of the students before proposing the roles that the students will assume in the project, always according to their preferences and assigning tasks in a flexible way. In this way, personalized study and work plans are defined.

The evaluation criteria will have to be defined a priori and illustrated to the students before the project starts. It is also preferable to involve the students in the discussion of the evaluation process, encouraging participation, so that the topic is clear from the beginning and can not generate problems of any kind.

In addition to proper planning of activities, a supervisory mechanism should be foreseen to monitor progress in order to avoid the accumulation of excessive delays.

Competitions between students can be easily made through the use of digital devices, with rules for the attribution of scores and reward mechanisms, to achieve an effective return.

All efforts made in this direction represent an important step towards improving and modernizing education, allowing students to be better prepared for their future.

### 4.12 Blended learning approach

Blended learning represents a point of contact between the traditional frontal lesson and e-learning, combining the advantages of traditional classes with those of virtual classes.

Naturally, on-site meetings and online self-learning units are planned, but mainly the teacher and the students interact also and above all outside the programmed on-site meetings, with the support of technology.

It is possibile to study anytime and anywhere because, thanks to cloud technologies, students can access to the teaching materials available on the technological platform from anywhere and at any time.

Blended learning is the most effective model of personalized teaching, as the degree of personalization is maximized according to the rhythm and needs of the students.

Recent studies also show that the ability to establish one's own learning pace with technology makes users less susceptible to stress or frustration, as well as better assimilate the proposed contents, as they autonomously decide the most appropriate moments to deal with the topics which require greater concentration.

A strong point is the constant monitoring of a student's progress, in correspondence of which the teacher must provide his feedback promptly.

The degree of autonomy that students have with this type of approach helps them to understand that the way they study in some way simulates the modus operandi they will use in their future work.

The decision-making process is stimulated a lot, as the student must continuously understand the point at which he is and must plan the continuation of his own path.

In summary, blended learning aims to eliminate the rigidity of the traditional teaching method, stimulating a personalized learning method, in order to develop the potential of each individual in the best possible way.

### 4.13 Problem solving activities in the blended learning context

The blended learning model is very flexible and allows the teacher to plan the activities for the students in a completely different way compared to another category of students. For example, workers who decide to undertake a course of study need the highest degree of flexibility.

More generally, this model allows the teacher to plan activities to be carried out collaboratively, in order to stimulate problem solving and the transfer of skills and abilities among group members. In this way all the potentials of this model emerge, as the members of the groups must realize one or more artefacts in a collaborative way, in which everyone's contribution is present and evident.

Therefore, among the many advantages that this model offers, it is certainly worth mentioning the possibility of sharing knowledge among the students, which represents the true essence of collaborative learning. The interaction among group members allows to share experiences, information and problem solving approaches, with the specific aim of generating added value for all the members involved.

# 5.

# COMPUTER-ASSISTED COLLABORATIVE ENVIRONMENTS

Collaboration is one of the fundamental factors of the teaching-learning paradigm, because the interaction between teacher and students, as well as that between the students themselves, has a facilitating force that allows to improve the learning process in a new way.

The design of teaching in a collaborative context is different from the classical one, in which the objectives to be reached are set and the times to be dedicated to the various topics are established. In the case of collaborative learning it is necessary to take into account the different points of view of the users and the fact that each experience is unique and does not represent the replication of a previous experience. With a collaborative didactics the users of the process will be enriched by sharing the experiences carried out together or, in other words, by a new competence that will be useful in the future work context.

Our interest is aimed at collaboration in a computer-mediated teaching-learning context, as we think that it will be increasingly important in our future, both educational and working.

Naturally, a computer-assisted collaborative environment must provide a natural and easy-to-use interaction to allow the user to achieve a goal in the best possible way. For this reason, in the following, we will refer to that part of the science that studies this topic, called Computer Supported Cooperative Work (CSCW).

## 5.1 Computer based learning

Computer-mediated learning is not born with a collaborative purpose and neither has the purpose of supplanting the traditional teaching activity in the classroom.

Computer-mediated learning can refer to a plurality of subjects who have an interest in training on a particular topic, but their priority is represented by the possibility of following the course according to their own personal study rhythm and not to collaborate with other subjects. For example, workers who undertake a course of study need a high degree of personalization of the path, having to reconcile the study with work and family commitments. In this case, both the course design and the software environment made available to the students will take into account the fact that the interaction with the other students should be limited to the maximum. In fact, in these circumstances the design of the course almost always involves the total absence of such interaction.

Moreover, in many courses where the theoretical aspects are more important than the practical ones, the need for collaboration with other students is not at all widespread.

Finally, on-site learning, which means that the teacher and students are in the same place and at the same time, will continue to be the most appropriate study practice in most cases.

This type of interaction makes it possible to ask for clarifications and just-in-time suggestions, that is, it allows us to respond to a need when it is born. Therefore, the advantages of traditional learning are concrete and tangible.

Likewise, distance learning does not aim to take the place of traditional methodology, but can provide the completion of different experiences. In fact, the online interaction tool that is made available usually offers much wider interaction opportunities.

Therefore, the teaching-learning method that is increasingly spreading is mixed (blended learning), as it combines the traditional "face to face" approach with computer-supported activities, because this new strategy brings together the advantages of the two methodologies, in presence and at a distance, discussed above.

## 5.2 Computer based cooperative environment

In a cooperative environment, the user interacts with other users to perform cooperative activities, using an appropriate software system that allows them to interact effectively. Obviously, the IT system must be designed to ensure the necessary interactions between users who work together to achieve a common goal, taking into account all aspects of remote communication, both positive and negative.

Software and collaborative tools in the literature are also called groupware. They are designed to facilitate the people involved to carry out a common task, to achieve one or more fixed objectives.

## 5.3 Groupware features

The software system that supports the carrying out of a cooperative activity must implement all those functionalities designed to facilitate the path that a group of individuals must perform to carry out the planned common activity. Our research work is aimed at designing a specific application of this type. Therefore, during the design phase it is necessary to decide the features to be implemented, so it is essential to have in mind precisely the features that a groupware application must have, that is: collaboration, cooperation, communication, information sharing, coordination, time and space, awareness.

## 5.4 Collaboration

The term collaboration indicates the need to work together to achieve a common goal. Collaboration can involve small groups, like two or three individuals, or one can be made up of a huge number. The number of individuals can not be defined a priori, as it depends on the specific problem that is faced. For this reason, the software must allow to define the groups of participants in an easy and flexible way and must allow the participants to work on the same activities at the same time.

## 5.5 Cooperation

Collaboration and cooperation are terms often mistaken for synonyms. In reality, there is a subtle difference. In practice, cooperation implies the carrying out of coordinated actions aimed at achieving a common goal, but the individual activities are carried out autonomously. For this reason, the software will have to provide goals to be achieved together, providing the possibility to carry out the related activities from different people.

### 5.6 Communication

With the term communication (from the Latin cum = with, and munire = to link, to construct and from the Latin communico = to share, to participate) we mean the process and the modalities of transmission of information from one individual to another (or from one place to another), through the exchange of a message elaborated according to the rules of a given code [2].

The communication between the members of a group is fundamental in a groupware, both to notify the beginning and the end of a given activity to the members of the group and to perform those steps that transform an artifact to its next version.

### 5.7 Sharing information and documents

The sharing software must allow all members of the group to access information and documents that represent the common activity. The software environment must allow them the insertion, updating and deletion of shared data, in a flexible way and, at the same time, it must be able to provide different levels of permissions, depending on the role that the specific user has in the context.

### 5.8 Coordination

The term coordination means the regulation and management of different elements so that the members work together in a coordinated way, that is integrated and harmonious, with the aim to achieve one or more common objectives.

Individuals responsible for coordinating resources, especially human resources or components of the structure, are very important, as their choices can lead to success or failure to achieve goals.

Coordination is directly related to the quality of the result. For this reason, a groupware must provide specific functionality for the person who manages and coordinates the activities. In this context, feedback functions are also fundamental.

### 5.9 Time and space

A groupware application must provide the ability to perform activities in the same place or in different locations, as well as synchronously or asynchronously. In this regard, it is possible to keep in mind the Johansen space-time matrix [3] which describes the different ways of carrying out an activity.

| | **Same time** (synchronous) | **Different time** (asynchronous) |
| --- | --- | --- |
| **Same place** (colocated) | **Face to face interactions.** decision rooms, single display groupware, shared table, wall displays, roomware, … | **Continuous task.** team rooms, large public display, shift work groupware, project management, … |
| **Different place** (remote) | **Remote interactions.** video conferencing, instance messaging, chats/MuDs/virtual worlds, shared screens, multi-user editors, … | **Communication and coordination.** email, bulletin boards, blogs, asynchronous conferencing, group calendars, workflow, version control, wikis, … |

*Table 1. the Johansen space-time matrix.*

Table 1 highlights four different situations that the groupware must be able to manage:

a) users work at the same time in the same place;

b) users work at the same time in different places;

c) users work at different times in the same place;

d) users work at different times in different places.

## 5.10 Awareness

Awareness is the user's perception of what other users of the system have been doing or are doing.

This aspect is particularly important in a groupware, as the goodness of this feature determines how much the system is able to help users to understand the state of the whole system.

Our research work is mainly focused on this aspect, in the conviction that the overall activity framework must be clear and understandable to all the members of the group, so that everyone can be aware of the individual interventions that have contributed to the overall activity. If all members have an overview of the status of the activity in a clear and immediate way, the system will allow them to optimize the time needed to complete the planned activity and, at the same time, increase the quality of the artifacts.

### 5.11 E-learning and problem solving activities

Our research interest concerns the integration between e-learning and problem solving activities in a collaborative environment. These concepts have been broadly discussed above, as we have highlighted the importance that these concepts have individually.

We addressed our research efforts in this direction, as we believe that this integration will become increasingly important and significant, within the future teaching-learning paradigm.

E-learning is a current research topic of considerable interest. The usability of these systems is a key feature of modern research. It is difficult to design educational applications in this sense, as e-learning users can be profoundly different among themselves for a variety of aspects, such as knowledge and skills, experience, motivation to learn, learning strategies, etc. For this reason, during the planning phase it is necessary to concentrate efforts to implement the features in an appropriate manner. Only in this way e-larning systems can be combined with specialized software so that they can be more effective and useful compared to the use of ordinary or general purpose tools.

We examined various software that could be useful for group activities related to problem solving, to be integrated with a standard Learning Management System tool.

### 5.12 Google Drive

We looked at the Google suite, where we identified Google Drive as a possible tool to support problem solving activities to be carried out collaboratively. This tool is certainly widespread and easy to use, allowing us to manage shared folders between groups of users. However, it is not able to give users the necessary awareness of the overall view of the progress of the shared activity, according to the definition of minimal requirements that we defined for the purpose and that we will present later in this work. In fact, simplicity of use can not compensate for this lack.

### 5.13 GitHub

We also evaluated GitHub, a global software development support tool that, unlike the first tool, is full of communication features between users and includes advanced features to show the progress of the activity. Our studies identified this tool as satisfying the minimal requirements to give users the awareness of the progress of the activity. On the other hand, its flexibility of use to manage software projects gives it limited usability to experienced users in computer science, but it is not suitable for less experienced users.

For this reason, we decided to continue our research by developing an environment that we designed and developed specifically to allow to effectively deal with problem solving activities in an e-learning environment.

## 5.14 Problem Solving Support Environment (PSSE)

We will present this tool later in this work, but we want to anticipate the reasons that convinced us to design and develop it.

We called this Problem Solving Support Environment (PSSE) software and we have intentionally and specifically implemented all the features necessary to give the environment the necessary simplicity of use (a feature that we found positively in Google Drive), as well as the features to ensure the overview of the progress of the activity by users (a feature that we found positively in GitHub), in favor of usability by users of all disciplines (functionality negatively evaluated in GitHub).

# 6.

# MINIMAL SET OF REQUIREMENTS FOR INTERACTION MECHANISMS: EXPERIMENTATION AND RESULTS

Blended learning is widely adopted by education agencies and organizations, as it is a flexible model in witch 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 work aims to propose a minimal set of requirements for interaction mechanisms to support problem solving activities in a collaborative environment.

We also report the results of a three-month experimental course (12 weeks) based on blended learning and problem solving activities; the results show that the aid of the proposed minimal set of requirements for interaction mechanisms significantly improves the learning outcomes when problem solving activities are carried out collaboratively.

### 6.1 Interest and motivation

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 [4]. 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 [5]. The quality of the e-learning systems based on these models is a crucial aspect, especially in the scope of the Bologna Process [6], a 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 [7]. 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.

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 they are 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.

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 courses organized by a training institute together with the corresponding results obtained contribute to determine its evaluation and, therefore, these results have repercussions on the organization itself.

In this work, 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 store all version of artifacts, providing the possibility to restore a previous version;

(iv) automatic notification messages 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 proposed several problems to be solved in a collaborative environment.

We implemented our minimal set of requirements using GitHub [36], that is a global software development tool and a traditional LMS, i.e. Moodle [38]. 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.

### 6.2 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 [8] [9] [10] [11].

Some studies have highlighted the importance of the interactive and collaborative platform and its features to increase the level of e-learner satisfaction [12], as well as the importance of the communication aspect for problem solving activities [13].

Other studies focused on user-centered approaches to ensure that design solutions meet users needs [14], taking into account students' learning styles in relation to problem solving skills [15].

Efforts have been made to improve online collaborative reasoning skills using scaffolding strategies [16], or innovative approaches have been used, such as the Flipped Classroom, to engage peer-to-peer communication that helps students understand and investigate, to build knowledge [17].

An important study highlights the fact that the co-occurrence of self-regulation, co-regulation and shared regulation in online collaborative learning varies according to the type of regulation strategies implemented by the group [18].

In addition, we cite the project Problem Posing & Solving (PP&S) promoted by the Italian Ministry of Education, Research and University, aimed to enhance teaching and learning using new methodologies and technologies, like an advanced e-learning platform, dedicated to teachers and students with powerful features for collaborative learning, e-tutoring and e-assessment [19].

Too many learning activities, as well as various learning materials and learning resources, are emerging in e-learning systems. Therefore, it is difficult for individual learners to select proper activities for their particular situations/requirements, because there is no personalized service function [20].

Consequently, some researchers have designed Recommender Systems, which aim to provide personalized recommendations to solve this issue [20] [21]. In this way, the system is able to profile the users and indicates the best method to carry out the e-tivities, depending on the user profile.

Salmon [22] 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') [22].

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 Salmon [22], 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 [22] 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 [23] [24] [35]. 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. [24], 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.

### 6.3 The proposed approach and research question

We observed several case studies that investigate the importance of problem solving activities in the e-learning context [25] [26] [27] [28] [29] [30] [31]. 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 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 decided to offer our contribution in this context through the definition of 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 and we hypothesized the minimal set of requirements, which are summarized in Table 2.

| 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 "artefacts", 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 |

*Table 2. Minimal set of requirements for interaction mechanisms to carry out collaborative problem solving activities in blended learning environment.*

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.

Furthermore, in this work we report the results of an experiment to validate the effectiveness of an implementation of the proposed minimal set of requirements for interaction mechanisms.

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 out minimal set of requirements using GitHub [36], that is a tool to support global software development, and a traditional LMS, i.e. Moodle [38]. 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.*

## 6.4 Experimentation design

The course entitled "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 two or three 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.

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 [32]. The pre-questionnaire results (Figure 1) highlight that there are no significant differences between the groups.

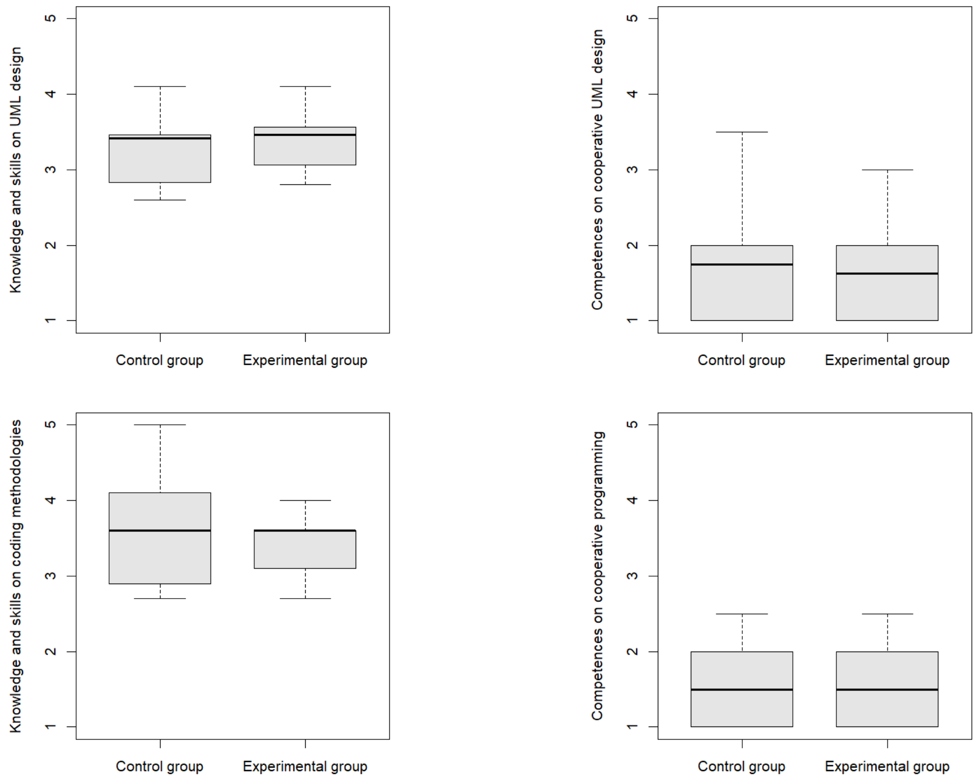



*Figure 1: Pre-questionnaire results: control group vs experimental group.*

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.

The course consisted of 6 learning modules (LM), whose timeline is shown in Figure 2. The description of the related activity and their duration (for a total of 12 weeks) is shown in Table 3.

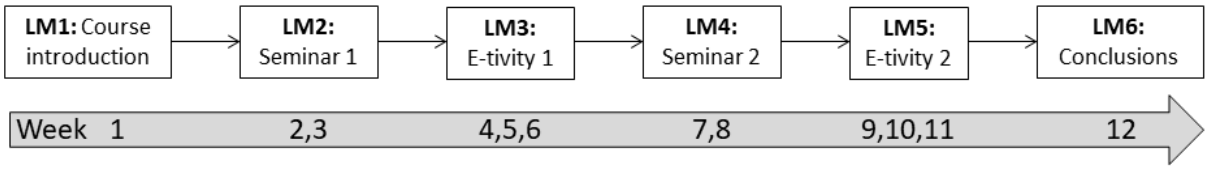



*Figure 2: Course design.*

| LM | Activity | Duration (weeks) |
|---|---|---|
| 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 |

*Table 3. Course modules.*

The experimentation focused on the two problem solving e-tivities scheduled in LM3 and LM5 modules. The first problem solving e-tivity consisted of exercises on UML design, while the second problem solving e-tivity proposed 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 [36] to carry out the problem solving e-tivities (with the aid of TortoiseGit utility [37] which improves the usability of the environment). In Table 4 we report the interaction mechanisms used to carry out the two problem solving e-tivities.

| Group | LMs | Interaction mechanisms |
|---|---|---|
| A (control group) | LM3 (E-tivity1)<br>LM5 (E-tivity2) | Standard: Moodle platform, Google Drive, emails, WhatsApp ad Facebook. |
| B (experimental group) | LM3 (E-tivity1)<br>LM5 (E-tivity2) | An implementation of the proposed minimal set of requirements for interaction mechanisms, using Moodle and GitHub (with TortoiseGit utility) |

*Table 4. Planned problem solving e-tivities.*

In Table 5 we report how the selected interaction mechanisms implement the minimal set of requirements. We monitored the system logs to check that students followed exactly the prescribed interaction model.

| 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 initializes 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 obtains 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 closes the *issue* initially created and all the group members receive the corresponding notification |

*Table 5. Implementation of our minimal set of requirements for interaction mechanisms.*

The artifacts produced by each student have been continuously monitored. The evaluation was carried out using the 0-100 scale in which the passing grade is 60, 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 were more motivated and suited. Consequently, their interest has ensured the maximum participation and an exemplary respect for the modalities to carry out all the planned activities.

### 6.5 Experimentation results

To address the research question above presented, 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 experimentation is based on the assumption that there were no significant differences between the two groups about knowledge and skills on UML design and programming, according the pre-questionnaire results, as reported in the previous section.

The assessment took 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 concluded 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, while the experimental group used an implementation of the minimal set of requirements for interaction mechanisms.

In this regard, Table 6 shows the mechanism to assign the points used to the course assessment.

| Activity | Assessment | Points |
|---|---|---|
| Partecipation, respect for the recommendations | activity log | 0-10 |
| Knowledge on concepts of Project management and Collaborative work | correctness of questionnaire | 0-30 |
| Collaborative e-tivity on UML design: problem solving activity | quality/quantity of contribution | 0-30 |
| Collaborative e-tivity on code implementation: problem solving activity | quality/quantity of contribution | 0-30 |
| Total | | 100 |

*Table 6. Grading points.*

In Table 7 we show results of descriptive statistical analysis for the complete course assessment. The values are related to the evaluation of the student artifacts, according to the 0-100 evaluation scale used.

| | Control group (*) | Experimental group (*) |
|---|---|---|
| Minimum | 66 | 74 |
| Maximum | 81 | 93 |
| **Mean** | **74.67** | **83.85** |
| Standard deviation | 5.10 | 6.12 |

(*) values are relative to the 0-100 evaluation scale.

*Table 7. Results of descriptive statistical analysis for the complete course.*

The results achieved by the experimental group are, on average, higher than the control group.

We analyze the collected data using the D'Agostino-Pearson normality test [34]. We show them in Table 8.

| | Control group | Experimental group |
|---|---|---|
| Complete e-course | 0.679506 | 0.649369 |

*Table 8. Results of D'Agostino-Pearson test (p-value).*

These results highlight a normal distribution in both cases, so we continue our analysis considering parametric independent sample tests [34].

Therefore, we proceed to calculate the p-value related to the difference of two means previously shown.

The choice of test to be performed was carried out according to the result of the F-test of equality of variance. Depending on the results obtained, Student t-test is used in case of equal variances, while the Welch t-test is used in case of unequal variances [34]. Table 9 shows results of these tests.

| | F-test | Student t-test |
|---|---|---|
| Complete e-course | 0.616655 | **0.001446 (< 0.01)** |

*Table 9. Results of F-test and Student t-test (p-value).*

In conclusion, a statistically significant difference is highlighted between measures of central tendency. In fact, results highlight $p<0.01$ significance level.

Furthermore, we analyzed separately the results of descriptive statistical analysis for the e-tivity carried out during LM3 module "Collaborative

UML design" (see Table 10) and for the e-tivity carried out during LM5 module "Collaborative code implementation" (see Table 11). The values are related to the evaluation of the student artifacts, according to the 0-30 evaluation scale used.

| | 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 10. Results of descriptive statistical analysis: e-tivity of LM3, i.e. "Collaborative UML design".*

| | 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.

*Table 11. Results of descriptive statistical analysis: e-tivity of LM5, i.e. "Collaborative code implementation".*

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 [34] in Table 12, showing a normal distribution in both cases.

| | Control group | Experimental group |
|---|---|---|
| E-tivity1: Exercises on UML design | 0.5693 | 0.1340 |
| E-tivity2: Exercises on code implementation | 0.5917 | 0.2332 |

*Table 12. Results of D'Agostino-Pearson test (p-value).*

Finally, we show in Table 13 the results of F-test and Student or Welch t-test, depending on the result of the first test [34].

| | F-test | Student t-test |
|---|---|---|
| E-tivity1: Exercises on UML design | 0.9403 | **0.0332 (< 0.05)** |
| E-tivity2: Exercises on code implementation | 0.0807 | **0.0096 (< 0.01)** |

*Table 13. Results of F-test and Student t-test (p-value).*

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.

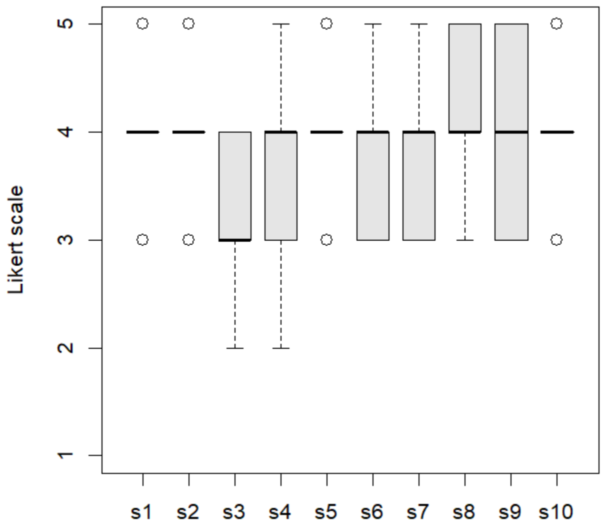
At the end of the experiment we proposed a final questionnaire related to the used interaction mechanisms. The answers are based on a five-point Likert scale: (1) strongly disagree; (2) disagree; (3) neither agree nor disagree; (4) agree; (5) strongly agree. The questionnaire statements are shown in Table 14, while the results are shown in Figure 3.

| Statements |
|---|
| s1) It was easy to use the proposed tool to implement the interaction mechanisms used |
| s2) The mechanisms of interaction are adequate to assist the development of problem solving e-tivities |
| s3) The expected interaction mechanisms are easily understandable and usable |
| s4) The automatic notification features provided were very useful |
| s5) Having had the opportunity to use a tool that implements mechanisms of interaction has allowed me a greater possibility of collaboration |
| s6) Having had the opportunity to use a tool that implements interaction mechanisms allowed me to learn more efficiently (I took less time) |
| s7) Having had the opportunity to use a tool that implements mechanisms of interaction has allowed me to learn more effectively (I understand better, in more depth) |
| s8) Having had the opportunity to use a tool that implements mechanisms of interaction has allowed me to acquire a practical skill that will be useful in a real work context |
| s9) Having had the opportunity to use a tool that implements mechanisms of interaction seemed to me an engaging and satisfying experience, in its entirety |
| s10) This type of approach should also be used in other courses |

*Table 14. Questionnaire statements.*

| Statement | Mean | St.dev. |
|---|---|---|
| s1 | 3.923 | 0.410 |
| s2 | 4.154 | 0.308 |
| s3 | 3.308 | 0.397 |
| s4 | 3.615 | 0.923 |
| s5 | 4.000 | 0.500 |
| s6 | 3.769 | 0.526 |
| s7 | 3.769 | 0.359 |
| s8 | 4.308 | 0.397 |
| s9 | 4.000 | 0.667 |
| s10 | 4.077 | 0.410 |

a) mean and standard deviation




b) corresponding boxplots

*Figure 3. Results of the final questionnaire; values are relative to a five-point Likert scale.*

### 6.6 Discussion of the results

The fundamental difference is that the experimental group has 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 artefacts themselves. The versioning provides the ability to store all versions of the project and, consequently, the students were tracked and controlled. In this way, it was also possible to highlight the contribution of each group member.

Furthermore, they had 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 [28] [29]. 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.

Finally, the results of the final questionnaire highlighted important aspects.

The responses to the statements s2 and s8 highlight 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, the responses to the s3 statement highlight the need to improve the comprehensibility and usability of the proposed functionalities, which directs our future work.

### 6.7 Threats to validity

To comprehend strengths and limitations of our experiment, we analyze the threats that could affect results and their generalization, according to Wohlin guidelines [33]. We also illustrate our efforts to mitigate as many threats as possible, considering that some of them are unavoidable.

### 6.7.1 Internal Validity

Threats of this type are influences that affect the experiment with respect to causality, without the researcher being aware of it. Thus, they threaten the conclusion about a possible causal relationship between treatment and outcome.

- Selection. This is the effect of natural variation in human performance. Depending on how the subjects were selected from a larger group, the selection effects can vary. It's worth noting that the effect of letting volunteers take part in an experiment may influence the results. Indeed, volunteers are generally more motivated and suited. In our experimentation, we asked for volunteers to mitigate this type of threat.

- Diffusion. This effect occurs when a control group learns from another group in the experiment. Supervisors avoided communication between the participants of different group during co-located sessions. In addition, the artifacts has been continuously analyzed to verify that they did not communicate with the other group.

### 6.7.2 External Validity

Threats to external validity are conditions that limit our ability to generalize the results of the experiment.

- Interaction of extraneous factors. In our study, the kind of experimental tasks may affect result validity. Thus, differences observed on the kind of experimental objects could be related to unknown extraneous factors. As much as we can be scrupulous, this kind of risk exists in every experiment.

- Specificity of the course topic. The course focuses on aspects related to computer science and the differences may not be observed in courses based on other topics. To mitigate this type of risk, we designed problem solving activities as generally as possible. Furthermore, we requested to carry out different activities, trying to amortise specificities.

### 6.7.3 Construct Validity

Construct validity concerns generalizing the result of the experiment to the concept or theory behind the experiment. Some threats are related to the design of the experiment, others to social factors.

- Specificity of interaction tool. The tool used to implement the minimal set of requirements for interaction mechanisms could be used improperly or in an uncontrolled manner. In order to mitigate this risk, students were trained on the interaction mechanisms they had to use and, in addition, the student activity were monitored, keeping them under control through the logs of the system.

### 6.7.4 Conclusion Validity

Threats to the conclusion validity are concerned with issues that affect the ability to draw the correct conclusion about relations between the treatment and the outcome of an experiment.

- Reliability of measures. The validity of an experiment is highly dependent on the reliability of the measures. This in turn may depend on many different factors. In this regard, to mitigate this risk we built a general evaluation grid, to be applied to all activities. Of course, the same evaluation grid was used to evaluate artifacts for both the experimental and control groups.

- Random heterogeneity of subjects. There is always heterogeneity in a study group. If the group is very heterogeneous, there is a risk that the variation due to individual differences is larger than that due to the treatment. For example, some participants may be more familiar with the course topics or with the specific tool used to implement the set of interaction mechanisms. In this regard, we have mitigated this type of problem by making a prior assessment of the participants skills, in relation to the course topics or the specific tool used. We gave an initial questionnaire and carried out an analysis of significance to show that there were no significant differences between the skills of the two groups.

## 6.8. Conclusions

In this Chapter 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, based on GitHub.

We presented and discussed a teaching experience "Project Management: a look ahead" about the management of a global software project. The course discussed 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.

In this regard, we highlight the fact that the experimental group used GitHub, which responds to our minimal set of requirements, while the control group used Google Drive, which is not compliant.

However, the final questionnaire results and the analysis of threats to validity suggest that is further work to conduct in this direction. Therefore, we developed a specific software to implement the minimal set of requirements for interaction mechanisms, so that the strategy is more easily applicable and usable in various contexts, in which collaborative problem solving activities can be usefully planned.

# 7.

# OUR SPECIFIC PLATFORM: PROBLEM SOLVING SUPPORT ENVIRONMENT (PSSE)

The results of the first experimentation suggested us to continue our research in the direction of design and development of a software specifically designed to support the carrying out of problem solving activities in a collaborative way, to be combined with standard e-learning tools.

## 7.1 Motivations

We designed and developed a software we called Problem Solving Support Environment (PSSE), whose features match the specifications indicated in our minimal set of requirement for problem solving.

The system proposed in the previous experimentation that provided for the use of GitHub showed its effectiveness, as the students of the experimental group obtained better results than those of the control group, as well as it responded to the need to highlight the individual contributions of the students and it allowed the teacher to adequately monitor the progress of the planned activities.

On the other hand, the results of the final questionnaire showed difficulties in using some GitHub features which, at times, are more complex than necessary. In some cases, when a user uses a feature incorrectly, he may find himself in trouble to cancel its effects, unless he is an expert of the system.

For this reason, we realized that the system we designed could be limited to courses in which the teacher and students are computer experts and we decided to develop the PSSE platform.

PSSE has the advantage of not being a general purpose software, as is Google Drive which, however, does not meet our minimal set of requirements. It also has the advantage of having a major usability, unlike GitHub which is a software more suited to software designers. Therefore, PSSE is also more suitable in those courses where students are not computer experts.

## 7.2 General characteristics

We decided to develop a portable software, so that it can be used on the most widespread operating system platforms (Windows, Linux, macOS, etc.).

We preferred to develop a platform that can be used by the web, accessible by teachers and students through a common browser (Chrome, Safari, Firefox, Edge, etc.), in order to overcome obstacles related to the difficulty of installation, as well as to confer the desired characteristic of portability.

Moreover, we envisaged the use of the platform also through the Apps, one designed for the teacher and the other for the students. At present, the Apps are available for Android platform only, but we also planned the development in the near future of versions for iOS and other mobile platforms.

### 7.3 Features

The first version, still under refinement, is available at the address reported in [39]. The home page shows the main menu in Figure 4, with separate sections for the administrator (Admin menu), teachers (Teacher menu) and students (Student menu).

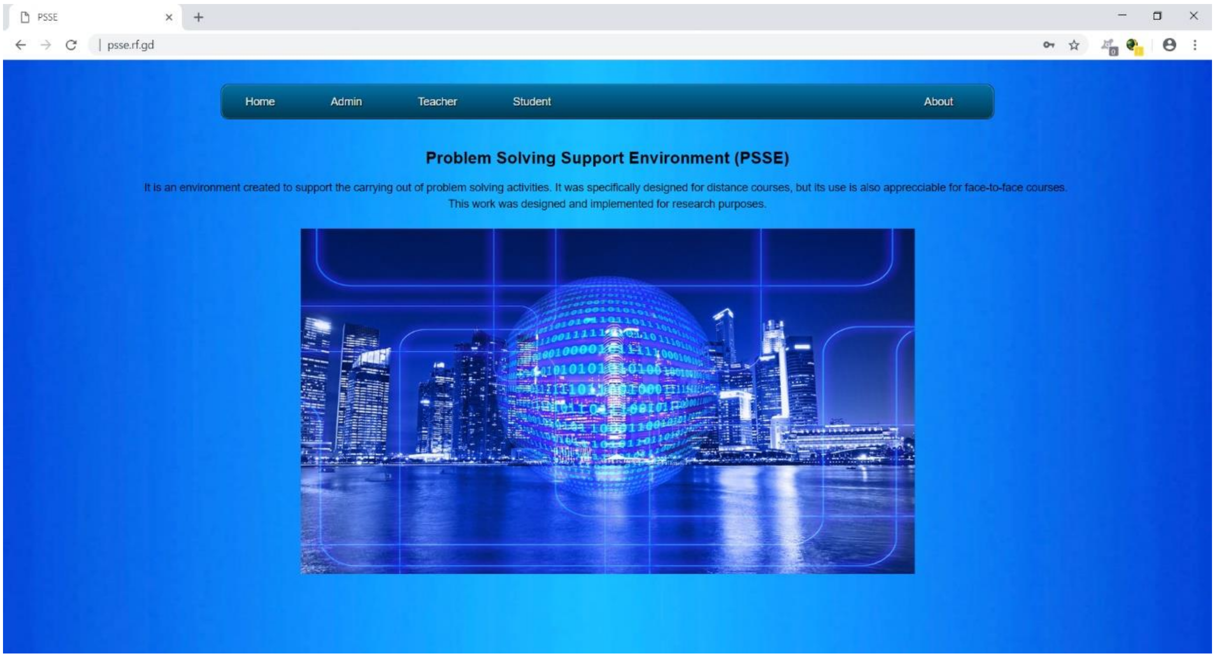



*Figure 4: Problem Solving Support Environment (PSSE)*

For the administrator there are various features, such as login to authenticate, the ability to create and manage the data of the courses, the teachers and the students, as well as the possibility to define some settings, as shown in the menu in Figure 5.

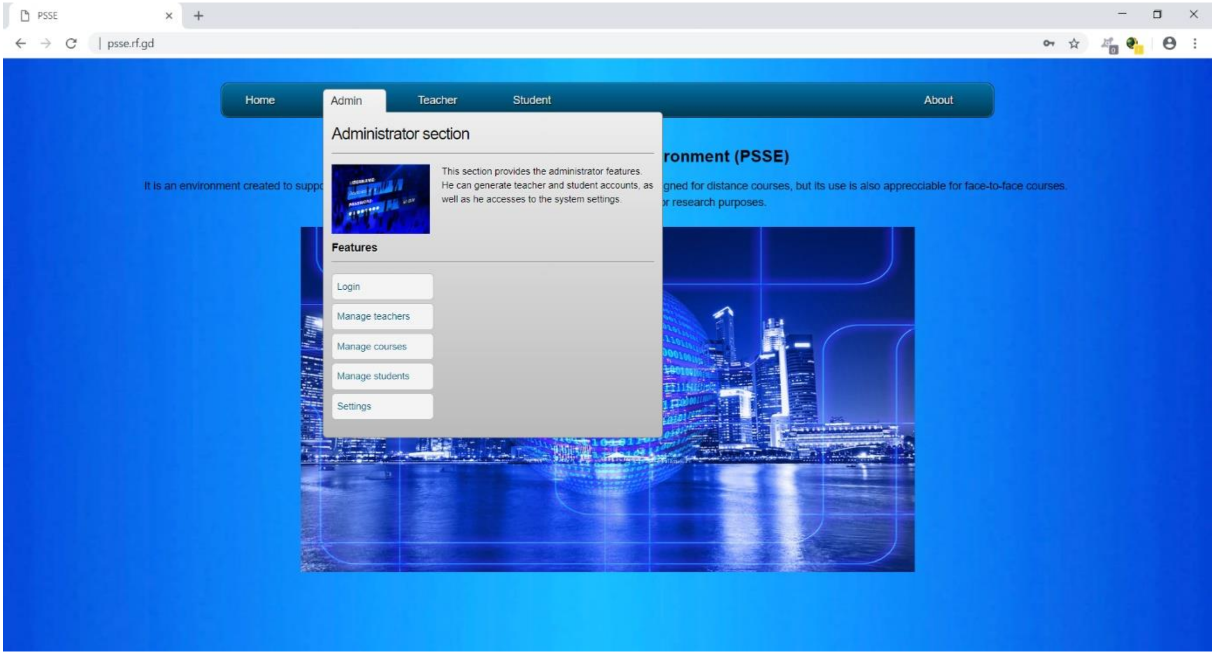



*Figure 5. Administrator menu*

For the teacher there are the features such as login to authenticate, the ability to define the activities to be carried out in problem-solving mode, to create the groups of students, as well as the possibility to assign the activities to the groups of students (see Figure 6).

We provided a specific feature to allow the teacher to monitor the activities being carried out by the students, as well as the possibility to download the app dedicated to himself.

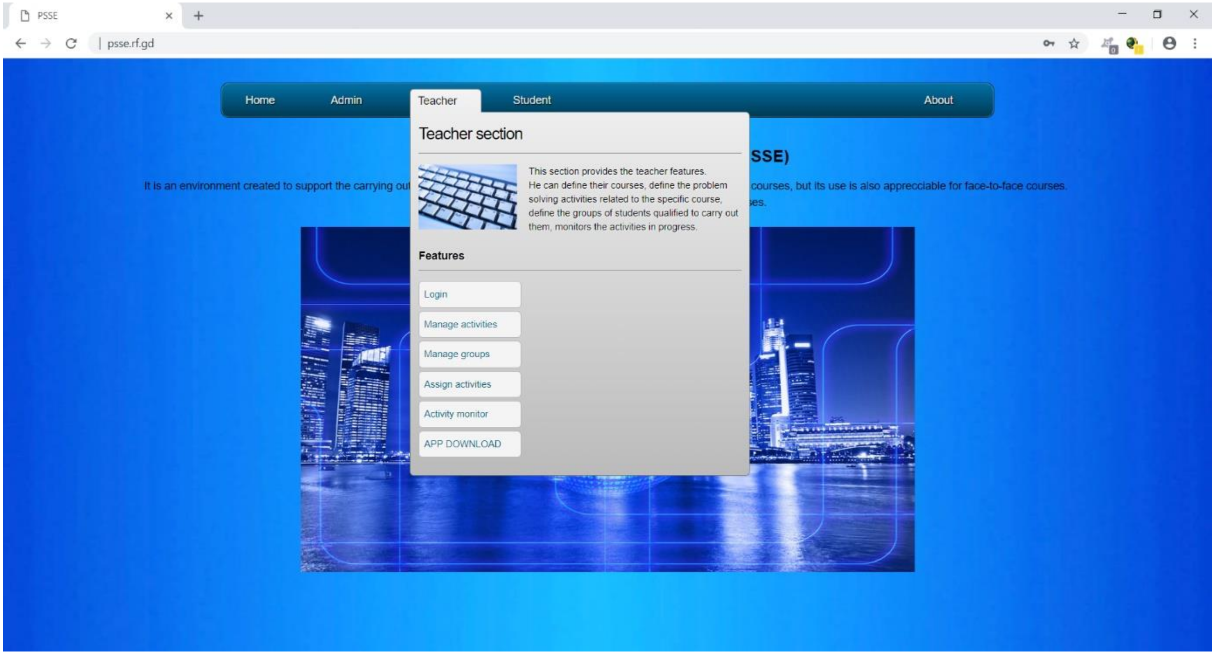



*Figure 6. Teacher menu*

Finally, the student is provided with the features, such as login to authenticate himself and the ability to view the in progress activities (see Figure 7). There is a specific feature to allow the student to send his contribution, the ability to show a report of the activities already completed, as well as the possibility to download the app dedicated to himself.

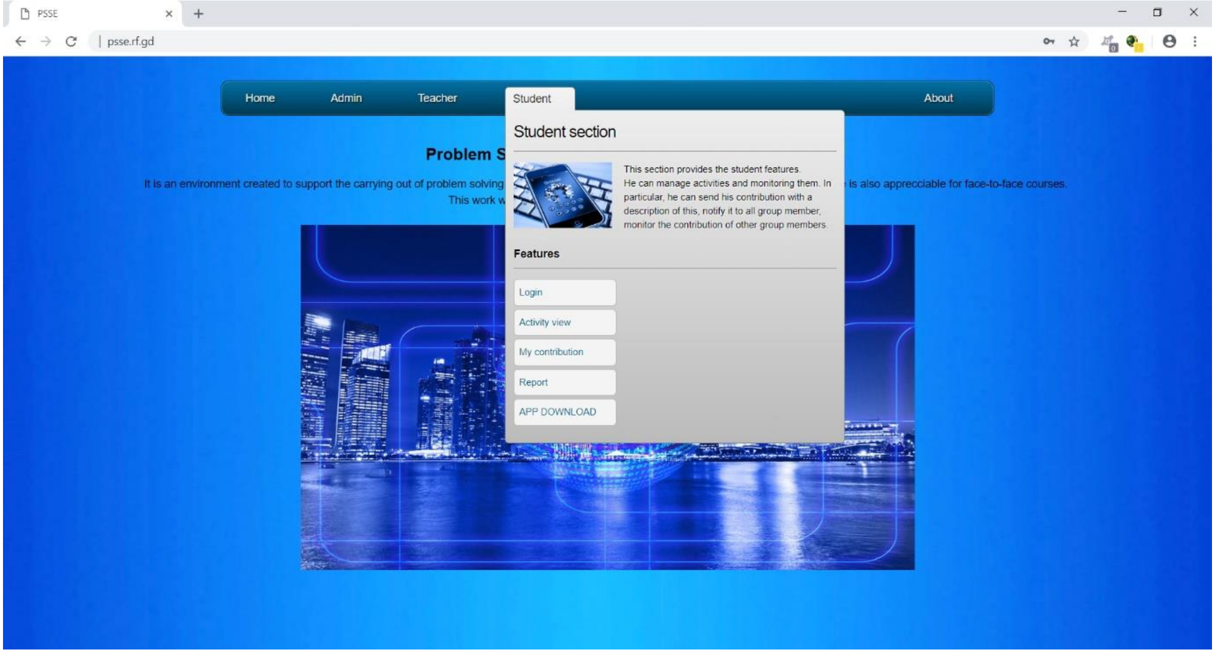



*Figure 7: Student menu*

## 7.4 Illustration of the main features

After defining the activities, the teacher assigns them to each group. Figure 8 shows the web page that allows the teacher to monitor the progress of activities. In this web page we can see that the teacher has created the type of activity called "CALCULATOR", which must be carried out by the two group of students named "Marius-Joseph" and "Anthony-Michael". The first table is related to the activity carried out by the first group composed by Marius and Joseph, while the second table is related to the same activity carried out by second group composed by Anthony and Michael.

The first row of the first table showing the “TASK TO DO: A SIMPLE CALCULATOR” description simply indicates that the teacher has assigned this activity to Marius and Joseph. The second and thirth rows of the same table indicates that Marius has sent a first contribution he described as "Calculator interface. This is a draft" and, then, a second contribution described as "Calculator. Interface completed". The teacher can download the version of artifacts using the appropriate button available in the "FILES" column, whose icon shows the classic arrow pointing downwards. In addition, the teacher can use the button in the “DIFF” column to understand which files the student has added, modified or deleted, compared to the previous version (which, in the first of two contributions, indicates only new files, as it is the first contribution).

The fourth row of the same table indicates that Joseph has sent a contribution he described as "JS code. I have also modified images".

The second table related to the activity assigned to the second group composed by Anthony and Michael shows that Anthony has sent a contribution he described as “Calculator. First version to be reviewed”.

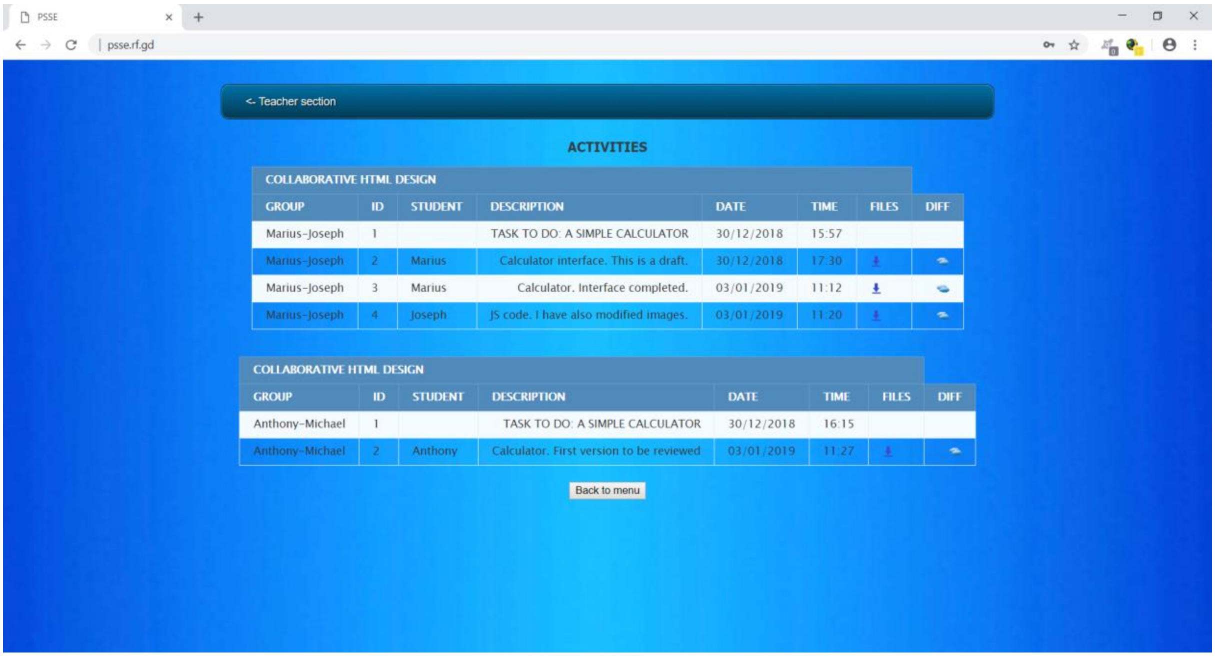



*Figure 8. Teacher monitor*

Figure 9 shows the feature that allow the teacher to highlights the differences between an artifact version sent by a student compared to the previous version. In this regard, the legend shows the provided icons, to understand if the files have been added, modified, deleted or if they are unmodified.

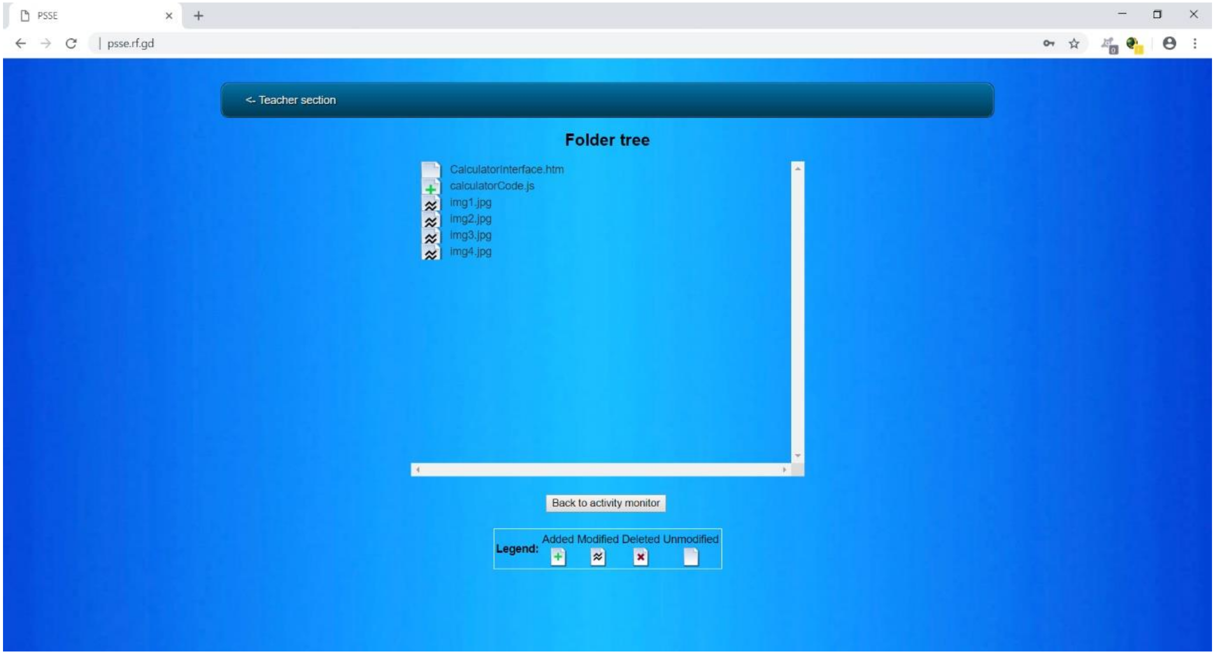



*Figure 9. Differences between artifacts*

Regarding the main features available to the student, Figure 10 shows the web page presented to the student when he decides to send his contribution. After choosing the folder cointaining the artifact, he have to describe his contribution and press the button at the bottom of the page to show the confirmation web page. This page in Figure 11 shows the files that the student is about to send, highliting the differences compared to the previous version stored on the server. The confirmation button located at the bottom of the web page allow to confirm the sending of the contribution and, consequently, the data are stored in the server database.

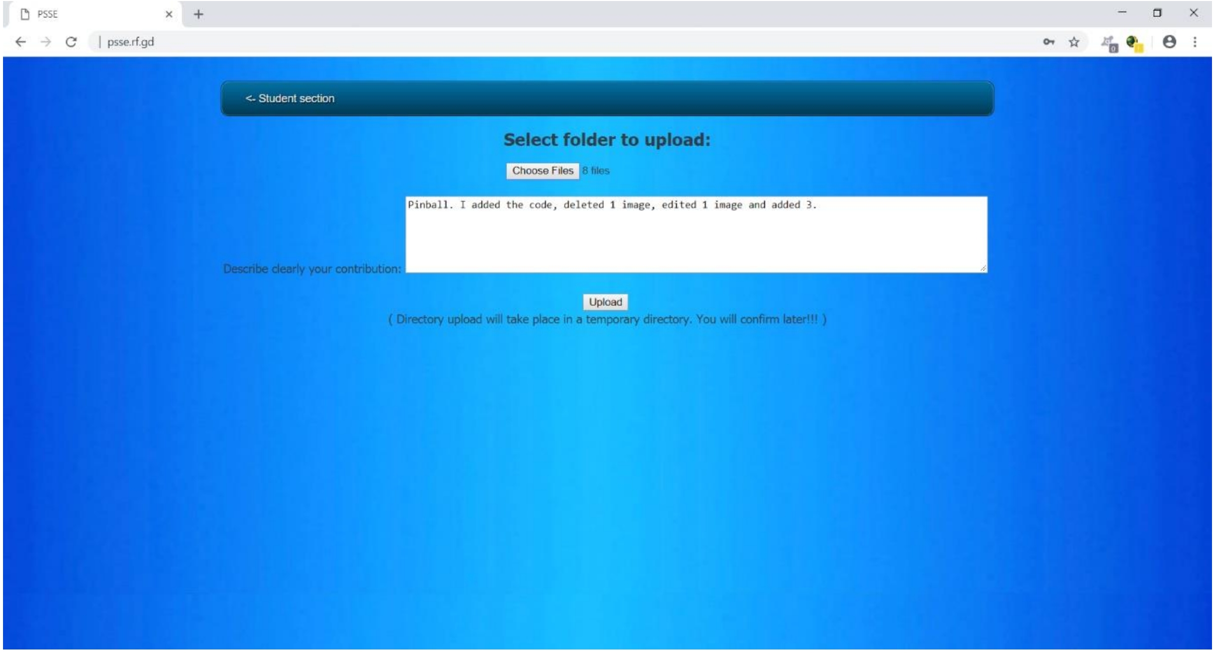



*Figure 10. The student sends his contribution*

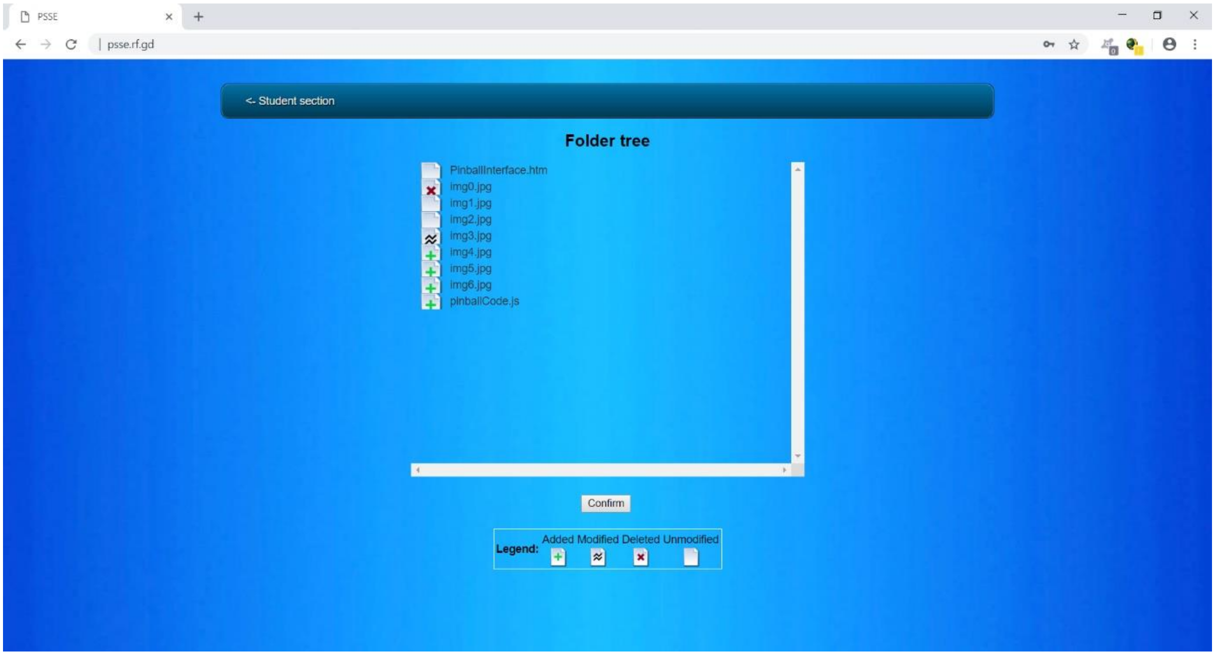



*Figure 11. Confirmation page*

## 7.5 Conclusions

We used PSSE to test with high school students during work-related learning activities.

In this way, we had the opportunity to compare the results obtained with the support of this software, in accordance with our definition of minimal set of requirements for problem solving, with those obtained with the tools we used for its implementation (Google Drive and GitHub) in the previous experimentation.

# 8. PROBLEM SOLVING SUPPORT ENVIRONMENT (PSSE): EXPERIMENTATION AND RESULTS

We continue our study on blended learning involving the carrying out of problem solving activities presenting the design of an experimentation that foresees the use of Problem Solving Support Environment (PSSE).

In particular, we remember that we designed and developed PSSE to implement our definition of minimal set of interaction mechanisms, as previously defined, to support problem solving activities to carry out in a collaborative environment.

We report the results of a 10 weeks experimental course based on blended learning and problem solving activities; the results show that the use of the PSSE platform significantly improves the learning outcomes when problem solving activities are carried out collaboratively. In particular, the results obtained are better than those obtained with the previous implementation of our minimal set of requirements for interaction mechanisms, which instead requires GitHub.

## 8.1 Interest and motivation

Our interest remains to investigate the effectiveness of our minimal set of requirements for interaction mechanisms as a learning facilitator in those courses that include problem solving activities, conducted in a collaborative way.

In this Chapter we show an experimentation of the use of PSSE, as an implementation of our minimal set of requirements for interaction mechanisms to support problem solving activities in a collaborative environment. We report the results of an experiment to validate the influence of such environment on the learning outcomes.

We started from the fact that we experimented our minimal set achieving positive results and that the final questionnaire showed strengths and weaknesses of the tools used. In particular, the prior explanation of how to use the proposed GitHub system was necessary to implement our minimal set. Furthermore, the high number of available features of the system itself has created difficulties for students. To solve the problems we decided to use the PSSE platform.

We organized a computer science course designed on the blended learning model entitled "Programming the web: HTML and JavaScript", lasting 10 weeks, in which we propose several problems to be solved in a collaborative environment.

We implemented our minimal set of requirements using PSSE, that is a platform that we have developed specifically for the purpose. We also used the previous implementation with GitHub to be able to compare the results.

We assessed the learning outcomes and experimental results are positive. Students appreciated this experience, as evidenced by a final evaluation questionnaire.

## 8.2 The PSSE approach and research question

PSSE aims to give the student the opportunity to interact with other students, to enrich their knowledge and skills to acquire competences to use them in a team.

This type of activity is particularly important when the course includes problem solving activities, since in this case the interaction between the members of the group is a fundamental aspect.

The communication mechanisms are designed and implemented to support the work of the students and the teacher. In this way, the students are aware of the progress of the cooperative work and the teacher is able to understand the contribution of a students compared to the others members of the group.

We report the results of an experiment to validate the effectiveness of PSSE to support the carrying out of problem solving activities.

In particular, we organized a computer science course designed on the blended learning model entitled "Programming the web: HTML and JavaScript", lasting 10 weeks), in which some problem solving activities were planned. We chose to implement out minimal set of requirements using PSSE. We considered appropriate to conduct a complete study, so we also used our previous implementation that required GitHub, in order to compare the different results obtained.

We formulated the following research questions:

RQ1: *In a blended learning course, students using interaction mechanisms to carry out the problem solving e-tivities provided by GitHub that implements the proposed minimal set of requirement achieve better learning outcomes related to the course objectives compared to the use of standard communication mechanisms.*

RQ2: *In a blended learning course, students using interaction mechanisms to carry out the problem solving e-tivities provided by PSSE that implements the proposed minimal set of requirement achieve better learning outcomes related to the course objectives compared to the use of standard communication mechanisms.*

**8.3 Experimentation design**

The course entitled "Programming the web: HTML and JavaScript" aims to achieve the theoretical knowledge and practical skills about the issues of developing dynamic web pages in a collaborative way.

Specifically, the course was designed by including knowledge regarding HTML constructs and practical skills related to dynamic web pages using JavaScript code, to be developed in team.

We designed specific e-tivities related to these issues, 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 enrolled in the fourth year of high school, hosted at the University of Molise for work-related learning during the 2017/2018 academic year. We divided the 30 participants in three groups of equal number of students, the control group and two experimental groups, the first that used GitHub and the other that used PSSE.

To ensure that there were no differences between the groups about previous knowledge and skills on HTML and JavaScript, we asked students to fill in a pre-questionnaire to assess their background. The pre-questionnaire results (Figure 12) highlight that there were no significant differences between the groups.

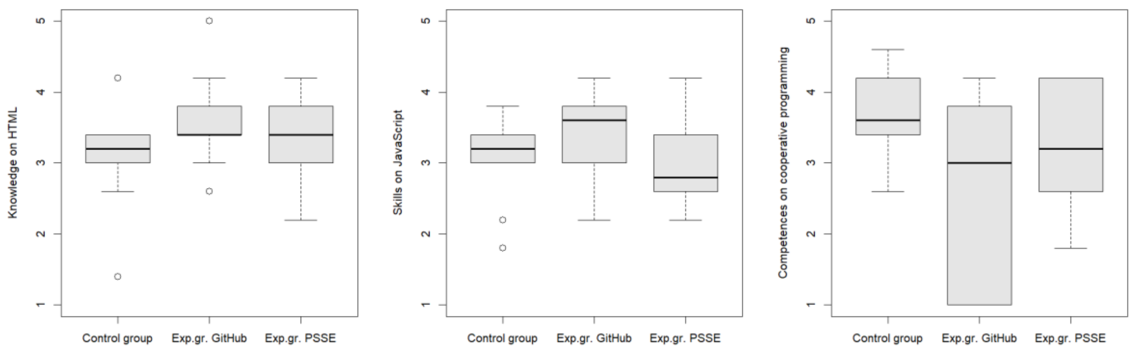



*Figure 12. Pre-questionnaire results: control group vs experimental groups.*

The course "Programming the web" 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.

The course consisted of 6 learning modules (LM), whose timeline is shown in Figure 13. The description of the related activity and their duration (for a total of 10 weeks) is shown in Table 15.

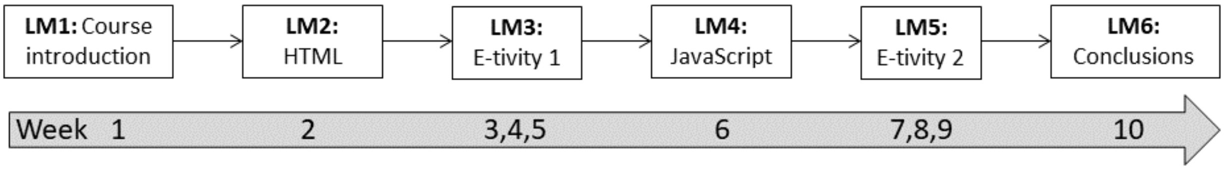



*Figure 13. Course design.*

| LM | Activity | Duration (weeks) |
|---|---|---|
| LM1 | Course Introduction: Web programming and collaborative work | 1 |
| LM2 | Seminar 1: HTML: performed exercises | 1 |
| LM3 | E-tivity 1: Collaborative HTML design: problem solving activities | 3 |
| LM4 | Seminar 2: JavaScript: performed exercises | 1 |
| LM5 | E-tivity 2: Collaborative JavaScript code implementation: problem solving activities | 3 |
| LM6 | Conclusions: Discussion of the experience | 1 |

*Table 15. Course modules.*

The experimentation focuses on the two problem solving e-tivities scheduled in LM3 and LM5 modules. The first problem solving e-tivity consists of exercises on HTML design, while the second problem solving e-tivity proposes some exercises on JavaScript 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 two experimental groups used Moodle to share the study material but the first group used GitHub [36] to carry out the problem solving e-tivities, while the second group used PSSE [39] to carry out them. In Table 16 we report the interaction mechanisms used to carry out the two problem solving e-tivities.

| Group | LMs | Interaction mechanisms |
|---|---|---|
| A (control group) | LM3 (E-tivity1)<br>LM5 (E-tivity2) | Standard: Moodle platform, Google Drive, emails, WhatsApp ad Facebook. |
| B (first experimental group) | LM3 (E-tivity1)<br>LM5 (E-tivity2) | Moodle and GitHub |
| C (second experimental group) | LM3 (E-tivity1)<br>LM5 (E-tivity2) | Moodle and PSSE |

*Table 16. Planned problem solving e-tivities.*

The artifacts produced by each student have been continuously monitored. The evaluation was carried out using the 0-100 scale in which the passing grade is 60, according to the individual contribution. Moreover, at the end of this experimentation student comments were collected.

Finally, we highlight that the students' interest has ensured the maximum participation and an exemplary respect for the modalities to carry out all the planned activities.

## 8.4 Experimentation results

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

$H_1$: *the use of the functionalities related to the minimal set of requirements for interaction mechanisms to carry out problem solving e-tivities provided by GitHub does not significantly affect the learning outcomes related to the course objectives.*

$H_2$: *the use of the functionalities related to the minimal set of requirements for interaction mechanisms to carry out problem solving e-tivities provided by PSSE does not significantly affect the learning outcomes related to the course objectives.*

The experimentation is based on the assumption that there were no significant differences between the groups about knowledge and skills on HTML design and JavaScript programming, according the pre-questionnaire results, as reported in the prevoius section.

The assessment takes into account all the activities carried out during the course.

In particular, LM1 addressed the fundamental concepts concerning the web programming and collaborative work; the students downloaded the material from the platform, to study it. LM2 presented some exercises on the HTML 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 JavaScript code implementation to prepare students for the e-tivity provided by the LM5, to be carried out in small groups. LM6 concluded 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, while the two experimental groups used an implementation of the minimal set of requirements for interaction mechanisms, the first using GitHub and the second using PSSE.

In this regard, Table 17 shows the mechanism to assign the points used to the course assessment.

| Activity | Assessment | Points |
|---|---|---|
| Partecipation, respect for the recommendations | activity log | 0-10 |
| Knowledge on concepts of Web programming and collaborative work | correctness of questionnaire | 0-30 |
| Collaborative e-tivity on HTML: problem solving activity | quality/quantity of contribution | 0-30 |
| Collaborative e-tivity on JavaScript code implementation: problem solving activity | quality/quantity of contribution | 0-30 |
| Total | | 100 |

*Table 17. Grading points.*

We show results of descriptive statistical analysis for the complete course assessment (see Table 18). The values are related to the evaluation of the student artifacts, according to the 0-100 evaluation scale used.

| | Control group (*) | Experimental group GitHub (*) | Experimental group PSSE (*) |
|---|---|---|---|
| Minimum | 64 | 66 | 69 |
| Maximum | 79 | 88 | 91 |
| **Mean** | **70.50** | **76.70** | **83.10** |
| Std deviation | 5.64 | 7.39 | 7.56 |

(*) values are relative to the 0-100 evaluation scale.

*Table 18. Results of descriptive statistical analysis for the complete course.*

The results achieved by the experimental groups are, on average, higher than the control group.

We analyze the collected data using the D'Agostino-Pearson normality test [34]. We show them in Table 19.

| | Control group | Experimental group GitHub | Experimental group PSSE |
|---|---|---|---|
| Complete e-course | 0.355661 | 0.720052 | 0.527824 |

*Table 19. Results of D'Agostino-Pearson test (p-value).*

These results highlight a normal distribution in all cases, so we continue our analysis considering parametric independent sample tests [34].

Therefore, we proceed to calculate the p-value related to the difference of the means previously shown.

The choice of test to be performed was carried out according to the result of the F-test of equality of variance. Depending on the results obtained, Student t-test is used in case of equal variances, while the Welch t-test is used in case of unequal variances [34]. Tables 20a and 20b show results of these tests.

| | F-test | Student t-test |
|---|---|---|
| Complete e-course | 0.432668 | **0,049318 (< 0.05)** |

*Table 20a. Results of F-test and Student t-test (p-value). Control group vs experimental GitHub group.*

| | F-test | Student t-test |
|---|---|---|
| Complete e-course | 0.395617 | **0.000512 (< 0.01)** |

*Table 20b. Results of F-test and Student t-test (p-value). Control group vs experimental PSSE group.*

In conclusion, a statistically significant difference is highlighted between measures of central tendency in both cases. In fact, results highlight $p<0.05$ significance level in the case of comparison with the experimental group GitHub and $p<0.01$ significance level in the case of comparison with the experimental group PSSE.

Furthermore, we analyzed separately the results of descriptive statistical analysis for the e-tivity carried out during LM3 module “HTML” (see Table 21) and for the e-tivity carried out during LM5 module “JavaScript code implementation” (see Table 22). The values are related to the evaluation of the student artifacts, according to the 0-30 evaluation scale used.

| | Control group (*) | Experimental group GitHub (*) | Experimental group PSSE (*) |
|---|---|---|---|
| Minimum | 17 | 17 | 21 |
| Maximum | 26 | 28 | 30 |
| **Mean** | **20.20** | **23.20** | **26.00** |
| Std deviation | 3.29 | 4.96 | 3.65 |

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

*Table 21. Results of descriptive statistical analysis: e-tivity of LM3, i.e. "HTML".*

| | Control group (*) | Experimental group GitHub (*) | Experimental group PSSE (*) |
|---|---|---|---|
| Minimum | 12 | 18 | 20 |
| Maximum | 29 | 29 | 30 |
| **Mean** | 18.80 | 23.60 | 26.40 |
| Std deviation | 6.71 | 4.79 | 4.09 |

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

*Table 22. Results of descriptive statistical analysis: e-tivity of LM5, i.e. "JavaScript code implementation".*

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

We present the D'Agostino-Pearson normality test [34] in Table 23, showing a normal distribution in both cases.

| | Control group | Experimental group GitHub | Experimental group PSSE |
|---|---|---|---|
| E-tivity1: Exercises on HTML | 0.2217 | 0.2173 | 0.3642 |
| E-tivity2: Exercises on JavaScript | 0.6009 | 0.2901 | 0.3998 |

*Table 23. Results of D'Agostino-Pearson test (p-value).*

Finally, we show in Tables 24a and 24b the results of F-test and Student or Welch t-test, depending on the result of the first test [34].

| | F-test | Student t-test |
|---|---|---|
| E-tivity1: Exercises on UML design | 0.2377 | **0.1286** |
| E-tivity2: Exercises on code implementation | 0.3287 | **0.0354 (< 0.05)** |

*Table 24a. Results of F-test and Student t-test (p-value). Control group vs experimental GitHub group.*

| | F-test | Student t-test |
|---|---|---|
| E-tivity1: Exercises on UML design | 0.7633 | **0.0015 (< 0.01)** |
| E-tivity2: Exercises on code implementation | 0.1556 | **0.0068 (< 0.01)** |

*Table 24b. Results of F-test and Student t-test (p-value). Control group vs experimental PSSE group.*

These results highlight a statistically significant difference between measures of central tendency only for E-tivity2 in the case of the comparison with the experimental group GitHub ($p<0.05$ significance level), while highlight a statistically significant difference between measures of central tendency for both the e-tivities in the case of the comparison with the experimental group PSSE ($p<0.01$ significance level).

Therefore, the null hypotheses $H_1$ and $H_2$ can be rejected, to accept the alternative hypotheses. Consequently, we can conclude that the use of the functionalities related to the minimal set of requirements for interaction mechanisms significantly affects the learning outcomes, with better results using PSSE.

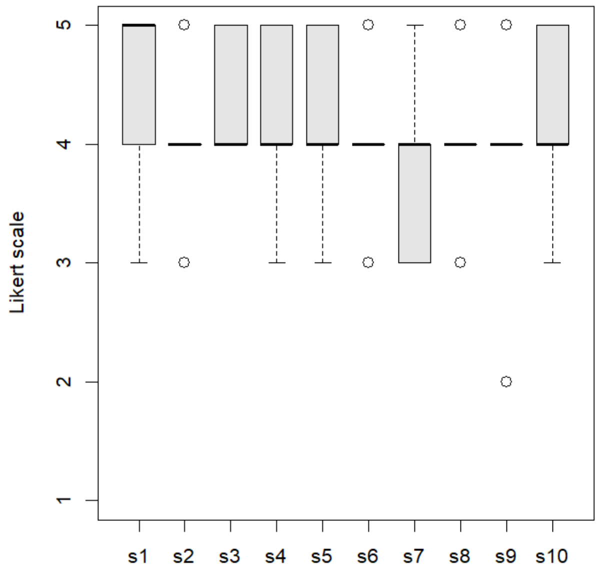
At the end of the experiment we proposed a final questionnaire about the used interaction mechanisms. The answers are based on a five-point Likert scale: (1) strongly disagree; (2) disagree; (3) neither agree nor disagree; (4) agree; (5) strongly agree. The questionnaire statements proposed to the students of the experimental group PSSE are shown in Table 25, while the results are shown in Figure 14.

| Statements |
| --- |
| s1) It is easy to use PSSE as a support tool for a course |
| s2) PSSE is adequate to assist design/programming in team |
| s3) The features provided by PSSE for inserting/deleting/editing files are easily understandable and usable |
| s4) The communication features between users of the same group (to know the contribution of the other users of the group) offered by PSSE are very useful |
| s5) PSSE allows greater collaboration between colleagues |
| s6) PSSE allows to learn more efficiently (to save time) |
| s7) PSSE allows to learn more effectively (to understand better, in greater depth) |
| s8) PSSE allows to acquire practical skills that will be useful in a real work context, as the team work is proper to the working environment |
| s9) Having the opportunity to use PSSE is an engaging and satisfying experience, in its entirety |
| s10) PSSE should also be used in other courses, even if the course topics are outside the information technology area, as it does not require high level computer skills |

*Table 25. Questionnaire statements.*

| Statement | Mean | St. dev. |
|---|---|---|
| s1 | 4.556 | 0.726 |
| s2 | 4.000 | 0.707 |
| s3 | 4.444 | 0.527 |
| s4 | 4.222 | 0.667 |
| s5 | 4.222 | 0.833 |
| s6 | 4.111 | 0.601 |
| s7 | 3.667 | 0.726 |
| s8 | 4.111 | 0.601 |
| s9 | 4.000 | 0.866 |
| s10 | 4.333 | 0.707 |

a) mean and standard deviation




b) corresponding boxplots

*Figure 14. Results of the final questionnaire; values are relative to a five-point Likert scale.*

## 8.5 Discussion of the results

The fundamental difference is that the experimental groups have 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 artefacts themselves. The versioning provides the ability to store all versions of the project and, consequently, the students are tracked and controlled. In this way, it was also possible to highlight the contribution of each group member.

Furthermore, they had 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 [28] [29]. 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.

Finally, the results of the final questionnaire highlighted a substantially positive experience, as it highlights the adequacy of the features offered by PSSE.

## 8.6 Threats to validity

To comprehend strengths and limitations of our experiment, we analyze the threats that could affect results and their generalization, according to Wohlin guidelines [33]. We also illustrate our efforts to mitigate as many threats as possible, considering that some of them are unavoidable.

### 8.6.1 Internal Validity

This type of threats can affect the experiment with respect to causality, without the researcher's knowledge. Thus, they threat the conclusion about a possible causal relationship between treatment and outcome.

- Selection. This is the effect of natural variation in human performance. Depending on how the subjects are selected from a larger group, the selection effects can vary. It’s worth noting that the effect of letting volunteers take part in an experiment may influence the results. Indeed, volunteers are generally more motivated and suited. In our experimentation, we asked for volunteers to mitigate this type of threat.

- Diffusion. This effect occurs when a control group learns from another group in the experiment. Supervisors avoided communication between the participants of different group during co-located sessions. In addition, the artifacts were continuously analyzed to verify that a group did not communicate with the other one.

### 8.6.2 External Validity

Threats to external validity are conditions that limit our ability to generalize the results of the experiment.

- Interaction of extraneous factors. In our study, the kind of experimental tasks may affect result validity. Thus, differences observed on the kind of experimental objects could be related to unknown extraneous factors. As much as we can be scrupulous, this kind of risk exists in every experiment.

- Specificity of the course topic. The course focuses on aspects related to computer science and the differences may not be observed in courses based on other topics. To mitigate this type of risk, we designed problem solving activities as generally as possible. Furthermore, we requested to carry out different activities, trying to amortise specificities.

### 8.6.3 Construct Validity

Construct validity concerns generalizing the result of the experiment to the concept or theory behind the experiment. Some threats are related to the design of the experiment, others to social factors.

- Specificity of interaction tool. The tool used to implement the minimal set of requirements for interaction mechanisms could be used improperly or in an uncontrolled manner. In order to mitigate this risk, students were trained on the interaction mechanisms they have to use and, in addition, their activity was monitored, keeping them under control through the logs of the system.

### 8.6.4 Conclusion Validity

Threats to the conclusion validity are concerned with issues that affect the ability to draw the correct conclusion about relations between the treatment and the outcome of an experiment.

- Reliability of measures. The validity of an experiment is highly dependent on the reliability of the measures. This in turn may depend on many different factors. To mitigate this risk we have built a general evaluation grid, to be applied to all activities. Of course, the same evaluation grid was used to evaluate artifacts for both the experimental and control groups.

- Random heterogeneity of subjects. There is always heterogeneity in a study group. If the group is very heterogeneous, there is a risk that the variation due to individual differences is larger than that due to the treatment. For example, some participants may be more familiar with the course topics or with the specific tool used to implement the set of interaction mechanisms. In this regard, we have mitigated this type of problem by making a prior assessment of the participants skills, in relation to the course topics or the specific tool used. We gave an initial questionnaire and carried out an analysis of significance showing that there were no significant differences between the skills of the two groups.

## 8.7 Conclusions

In this Chapter we showed an experimentation in which the experimental groups had the opportunity to use an implementation of our definition of minimal set of requirements for interaction mechanisms.

We presented and discussed a teaching experience "Programming the web: HTML and JavaScript" about the HTML design and JavaScript code implementation. The course discussed the issues of the web programming and collaborative work.

The course included two problem solving e-tivities to carry out practical activities about HTML design and JavaScript code implementation. 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 groups compared to the control group, highlighting better results with PSSE than the previous implementation with GitHub. Furthermore, the comments of the students highlight the adequacy of the features offered by PSSE.

# 9.

# CONCLUSIONS

In this thesis, we analyzed the main aspects of problem solving and the peculiarities of the decision-making process, with a special emphasis on the education environment, and we presented our contribution to research. We proposed the definition of a minimal set of requirements for interaction mechanisms necessary to address problem solving activities in a collaborative environment. This idea is opposed to those choices in which it is preferred to provide guidelines or recommend tools to be used to carry out different activities in the teaching-learning context.

Therefore, we believe that our definition is the basis to implement a whole series of practical solutions to tackle problem solving activities.

In support of this thesis, we designed a first implementation that draws a practical solution, in order to define a correspondence between our minimal set of requirements and the way in which the communication tools are used. This solution is based on Moodle and GitHub and we proposed an experimentation by designing a 12-week course entitled "Project management: a look ahead", which proposed some problem solving activities. We analyzed the statistical results and we could verify the effectiveness of the proposed solution, as it showed an increase in learning outcomes in terms of competences. The proposal made it possible to highlight the contribution of each student and the teacher was able to monitor the progress of the activities, but the results of the final questionnaire showed difficulties in using some software features. In fact, GitHub is not a tool designed for teaching-learning and its use has required a training phase in order to explain to learners how it is used; indeed, in some cases it requires multiple steps to implement a single feature and sometimes it requires users to be computer experts. Therefore, we understood that it was necessary to improve the usability of the proposed system.

As a result, we designed a second implementation by developing a specific platform to implement our minimal set of requirements, in order to carry out problem solving activities in a collaborative way, which we called Problem Solving Support Environment (PSSE).

To test its effectiveness, we proposed a second experimentation through a 10-week course called "Programming the web: HTML and JavaScript", in which we planned different problem solving activities to be carried out in a collaborative way. Also, in this case we analyzed the statistical results, which showed its effectiveness in terms of better learning outcomes.

The realized platform is now easily usable and, for this reason, in the near future we want to improve the features of the platform. Furthermore, we want to design experiments to carry out courses in different fields. In particular, we want to experiment our platform to carry out courses in a different field than computer science.

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