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# *Problem Posing and Solving: Strategic Italian Key Action to Enhance Teaching and Learning Mathematics and Informatics in the High School*

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**Abstract**— The Project PP&S, Problem Posing & Solving, is part of a set of initiatives promoted by the General Directorate of the Italian Ministry of Education, Research and University, aimed to support the many innovations in the High School. Its main goal is to enhance teaching and learning Mathematics and Informatics using new methodologies and technologies, like an e-learning platform integrated with an Advanced Computing Environment and with a web conference system. This integrated environment makes available to teachers and students a powerful set of features for collaborative learning, e-tutoring and e-assessment.

**Keywords** — *advanced computing environments; automated assessment; collaborative learning; computational thinking; computer science; e-learning platform; Informatics; high school; learning communities; living lab; Mathematics; problem posing and solving.*

## I. INTRODUCTION

In 2012 the Italian Ministry of Education started a strong action in order to improve the quality of the educational process, by acting on teachers' training in order to overcome several critical situations undermining Italian education system. The principal problematics identified by the government, highlighted by the results of international surveys, were a weakness in the preparation to deal with problems in quantitative terms, a nearly exclusively disciplinary nature of the formative approach, a wide prevalence of a traditional didactic approach to deduce from the general topic (theory) to the specific issue (applications, too often confined to an ancillary role), and a delay of the impact of ICT on contents and on organisation of formative activities. In the following paper we are going to analyse the critical situation of Italian

school system with respect to the international context (paragraph II); the response of the Government through the PP&S Project (paragraph III), the activity of the project and the results obtained (paragraphs IV, V and VI), the project within the European scenery (paragraph VII) and the future perspectives (paragraph VIII).

## II. CRITICS OVER ITALIAN SCHOOL SYSTEM

In 2012 OECD-PISA surveys [22] Italian students placed below the world average as regards the elaboration of real models. The results evidenced the tendency to perform better when the assessment is based on their capacity of interpreting-applying-evaluating mathematical results, and to get wrong when the assessment requires the ability to formulate situations in a mathematical way. The same difficulty has been evidenced also by the national survey INVALSI. Other European surveys show that Italy is in danger of “missing the boat” in the ICT, see [12], [19].

Another problematic of Italian Education can be pinpointed in the deficiency and inefficiency of the connection between school and working world. On one hand, schools do not renounce to fill completely the educational space developing the disciplinary knowledge, rather than including a component addressed to the working environment; on the other hand, the world of work requires competences which school usually do not provide.

In 2006 European Parliament [25] suggested a set of key competences for the permanent learning which need to be developed; in particular the situation examined before makes clear that, in order to adapt to the European recommendations, Italian school system should invest in increasing the competence in Mathematics and Science and the level of

digital competence (Third and Fourth Key European Competence of Active Citizenship).

### III. THE PROJECT PROBLEM POSING & SOLVING: AIMS AND MILESTONES

The Project Problem Posing & Solving, PP&S, [20], is one of a set of initiatives promoted by the General Directorate of the Ministry of Education, Research and University, aimed to contrast the critical situation of Italian school and to bring innovation in teaching.

The project gathers among the leading proponents the Italian Association for Automatic Computing (AICA), the National Research Center (CNR), the National Industrial Unions, the University of Turin and the Polytechnic of Turin. Culturally focused on problem solving, it aims to tap the invaluable potential of information technology as an enabler of innovation, through the development of connections between Mathematics and Computer Science, [23], [21], [26], [28].

Main focuses of the project include:

- strengthening computer science culture, enhancing its role as a scientific discipline, by introducing specific courses in the first two years where it is not currently fully covered;
- founding education processes combining Logic, Mathematics and Computer Science;
- building a culture of "Problem solving & posing", by investing across the broad disciplinary group of subjects, within the various curricula, adopting a systematic activity based on the use of the logical-mathematical-based computer science in the formalization, quantification, simulation and analysis of problems of various complexity;
- ensuring growth of computer science-based training of trainers called to accompany the transformation process;
- adopting a significant amount of social network activity and virtual learning environment, sharing learning materials, teaching supplies, tutoring, mentoring, self-evaluation.

At the beginning, the project counted 100 schools, which acted as "poles" of territorial networks, 150 teachers and students of the last three high school years. After the first two years it saw the active participation of 800 teachers, more than 400 schools and 12000 students, and it opened to all the five high school years [15].

In the first year of the Project's life the attention was focused on Mathematics, on how to use new technologies, in particular a Content Learning Management System and an Advanced Computing Environment, in order to build new teaching modules in Mathematics in the logic of problem posing and solving. The Faculty of Science of the University of Turin had a big experience in e-learning and learning technologies, and put at service of the Project the asset (based on Moodle, [18], and the Maple Suite, [14]) built and used with success for several years in teaching Mathematics for all students of the Faculty [1].

The first 150 teachers from all over Italy initially gathered

in Verona and attended a brief training in presence; immediately they created a community on Moodle, and began to practice a strong collaborative learning. Since the early days, a very careful and precious service of tutoring was activated on the platform. Starting from February 2013 150 communities of students, the teachers classes, arose: these were communities of real cooperative learning. They could not only learn at school, in the laboratories during Mathematics lessons, but also try to solve problems together inside the content learning management system, [29].

In the second year, 2013/2014, a community of Computer Science teachers arose on the platform. This community works together with the Maths teachers' community, and it started to prepare two innovative modules to be inserted into the curricula of the first two years of high school, [3], [5].

In 2013/2014 it was also launched a strong program of training for the teachers who asked, voluntarily, to come to know the philosophy of the Project, [17].

In the current third year of the project's life, the principal miles stones are: to open the project to a higher number of schools, to collect and make available all the materials and the learning paths created to all Italian teachers, sharing good practices within an international context, with actions of exchange of experiences by means of European cooperation initiatives. The web site of the e-learning platform Moodle of the Project is [www.progettopps.it](http://www.progettopps.it); Fig. 1 shows the homepage.

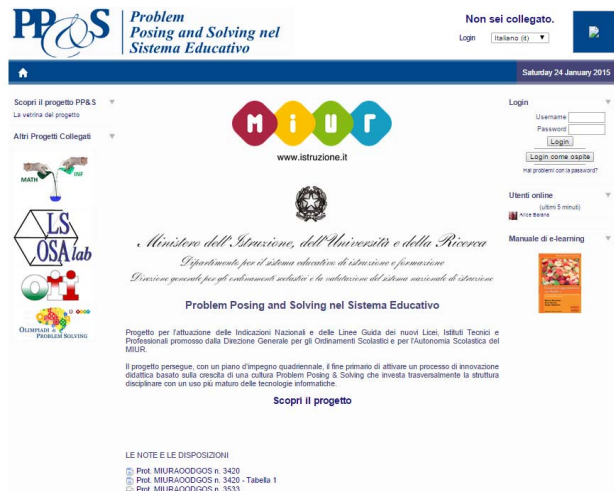


Fig. 1. Homepage of the Moodle platform of the PP&S Project.

### IV. BEST PRACTICE COMMUNITIES OF TEACHERS AND STUDENTS ON E-LEARNING PLATFORM

One of the key strength of the PP&S project is the creation of best practice communities of teachers and students on the e-learning Moodle platform, [7], [16]. Members of the communities of teachers constantly and autonomously improve their skills, performing a perfect example of collaborative learning. In particular, they have access to synchronous and asynchronous tutorings which help them to overcome their initial difficulties with the new methodologies and technologies and offer a constant support in order to

improve the mastery of those tools and their application to the problem-posing and problem-solving philosophy. Tutors are constantly present and well-prepared to answer any doubts and motivate teachers in their work; in addition a helpdesk service provides immediate technical support at any time (service desk is active 5/7, with answer times of 15 minutes and solution of the problem in 2 hours for the pre-authorized claims). Some advice of expert educational consultants is offered, to add value to teachers' work. Didactic material, prepared by tutors and ready to be used in class, both for learning and assessment, is available on the platform. Teachers can share with their colleagues interactive files, question banks and assignments for self-assessment. They can also practise the cross-coursing visiting other courses and analysing how resources and activities are proposed. The networking and personal connections boosted in e-learning communities are decisive for the discovery and the exchange of experiences, new ideas and teaching strategies. The contents shared and the digital material produced can be continuously renewed, updated and extended. Sharing means being open to connections, interested in the production of colleagues, but especially in their opinion about your work, and that leads to a professional development.

The collaborative learning allows to break the physical distance, teachers can communicate and work together simultaneously while sitting behind a screen from every Italian town. Feeling part of a community reduces the sense of failure which might arise after the first difficulties, realising that you are not alone but there are many others sharing similar problems.

Besides the teachers communities, [10], the platform also accommodates students communities, constituted by the classes enrolled in the project. There every teacher plays the role of tutor with his class. Students have access to resources, as files and videos, made available by their teacher; they can complete Moodle activities, assignments and tests for evaluation and self-evaluation, solve problems with their class mates, discuss through forums; everyone gives his personal contribute in the logic of cooperative learning. Moreover, many classes join the project with teachers of different subjects (Mathematics, Computer Science, Physics, Natural Sciences, Economy...): that promotes the learning and building of cross-cutting competences. Working in platform allows to go beyond the rigidity of scholastic timetables and outside the classroom; learning, still monitored and supervised by the teacher, is extended to informal moments and it is transformed into a continuous and active process which sees the student as protagonist and the teacher as facilitator. Collaboration, cooperation, belonging to a community, constant availability of resources, multidisciplinary of knowledge, are all key factors capable to turn learning into a lifelong, lifewide and lifewise process.

## V. TECHNOLOGICAL SCENARIOS FOR MATEMATICS AND COMPUTER SCIENCE

### A. Advanced Computing Environment for the Problem Solving and for the E-Assessment in Scientific Subjects

In order to work in the Problem Posing and Problem Solving methodology, didactic activities are heavily based on exploitation of an Advanced Computing Environment (ACE). In particular, the Maple Suite has been chosen to serve the purposes of the project.

The Maple Suite consists of four software components. The first one is Maple, a Mathematical Engine capable to perform symbolic and numerical computations, to visualise geometrical objects in two or three dimensions (e.g.: in Fig. 2 the Moebius strip is displayed), to deal with any part of Mathematics by means of numerous packages of commands. Latest developments of Maple are addressed to its employment in education, with a set of interactive applications designed to an effective learning.

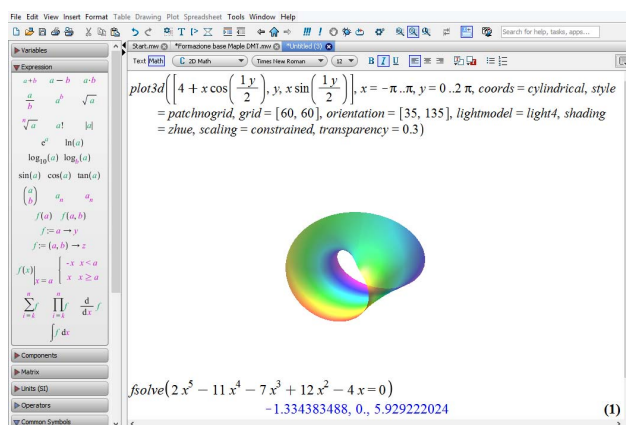


Fig. 2. Maple worksheet.

Thanks to the second component, MapleNet, Maple worksheets can be made available on the web and its implementation on Moodle, developed by University of Turin, allows interactive files to be added in the Moodle courses and read in a page of the platform, maintaining their interactivity.

MapleSim, the third component of the Maple Suite, is a virtual laboratory designed to the physical modelling and mathematical simulation, as Fig. 3 shows. It is appreciated especially in technical institutes where electronics, mechanics and physics are the core subjects and the lack in laboratory facilities and technicians do not allow the conduction of physical lab experiments, [9].

The Maplesoft Testing and Assessment solution (Maple T.A.) is a web application studied for the e-assessment and particularly suitable for Mathematics: thanks to the Maple Engine behind, it is able to deal with, understand and evaluate mathematical expressions. Mathematical answers are accepted in all the equivalent correct forms, making it possible to go beyond the multiple choice and true or false testing modalities and assess true mathematical skills and competences.

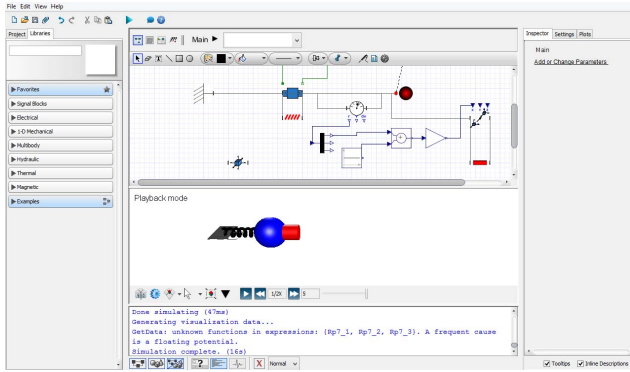


Fig. 3. Simulation of a spring with MapleSim.

Maple T.A., also integrated within Moodle, is successfully used both for the summative class tests at school and for the formative assessment, from home, to check the comprehension, monitor the learning and deliver contents. Fig. 4 shows a Maple T.A. question, which asks to insert a non-elementary mathematical formula; the student's response is automatically graded and commented.

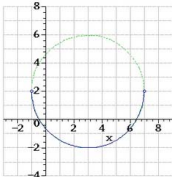
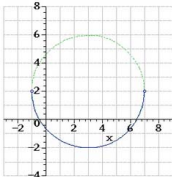

Your response	Correct response
Find the equation of the function displayed in the blue graphic. Y = $2 - \sqrt{16 - (x-3)^2}$ (0%)	Find the equation of the function displayed in the blue graphic. Y = $2 - \sqrt{16 - (x-3)^2}$
	
 Incorrect	
<p>Total grade: 0.0/1.0 = 0%</p> <p>Comment: The graphic displays the circle of centre (3,2) and radius 4. In particular we have to consider the inferior semi-circle, whose equation is <math>y = 2 - \sqrt{16 - (x-3)^2}</math>.</p>	

Fig. 4. Graded and commented answer with Maple T.A.

All schools joining the project have been provided with Maple licences, so that part of Maths lessons can be held in the computer lab and with the use of Maple. Students, who are mainly digital natives, learn quickly how to work with an ACE, since the first year of high school; the use of the computer makes Maths lessons stimulating and Mathematics more attractive. It also facilitates the learning, which can be freed from heavy and little meaningful computations, leaving time for dedicating to the deep comprehension of topics and connections between different parts of the subject. Algebraic relations become clear when graphically displayed, students can explore their properties and make conjectures, which is important for studying Mathematics. Maple also enhances the interaction between Mathematics and Computer Science, not only for the application of technologies in dealing with Mathematics, but also for the possibility to create short procedures with a programming language based on C involving mathematical objects. The mastery of an Advanced Computing Environment is a useful skill for students,

expedient for a future employment in the job world, as many companies use ACEs in planning and production.

### B. Living Lab and Computational Thinking in Computer Science

Problem Posing and Problem Solving methodology is strictly connected to Computational Thinking (as defined by G. Wing: "Computational thinking is the reasoning processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" [27]). This definition can be assumed as a reference point with respect to the objectives pursued by the PP&S project, as the terms "formulating problems" and "formulating solutions" suggest.

Teachers of Computer Science involved in PP&S adopted a "Living Lab" approach, [6], [8], [13], where the attention is focused first on a problem easily perceived by everybody and immediately understood in terms of effects, so that a reference framework could be shaped using available tools widely spread in the CS community.

As programming language was suggested Python, [24], for his simplicity as well as because it allows a strong interaction with the advanced computing environment Maple and MapleSim. Of course in different kinds of secondary schools teachers can use also more than one programming language in order to allow to satisfy different requirements.

## VI. E-TRAINING FOR ALL TEACHERS PARTICIPATING TO THE PROJECT

In 2014 the Italian Ministry of Education promoted a strong action of training directed to all Italian teachers, the strongest one after the Computer Revolution and the introduction of P.N.I. (National Informatics Program) in the nineties, when Computer Science was inserted in scholastic curricula as a compulsory subject. The training Program was supported by a dedicated funding, [17].

Within one year, besides the 800 teachers already trained and working in platform, other 1700 started the training through blended courses. Figures 5 shows the numbers of trained teachers in each Italian region. More than 2500 teachers, one out of three Italian Maths and Computer Science teachers with tenure, have been introduced to the PP&S methodologies, [4].

The training includes some brief lessons in presence, held by University professors or by expert teachers, and provided in the geographical area of residence; after that, it continues online on the e-learning platform. During the training teachers learn how to use Moodle, Maple, Maple TA and MapleSim. During the training, teachers begin to create didactic material, which can directly be proposed to students: problems, questions for the assessment etc.

Learning to use an ACE and an e-learning platform and adopting them in the didactics requires a great effort and investment of time, but it will be refunded by personal and professional development and by major satisfaction in learning and in the results achieved by students.



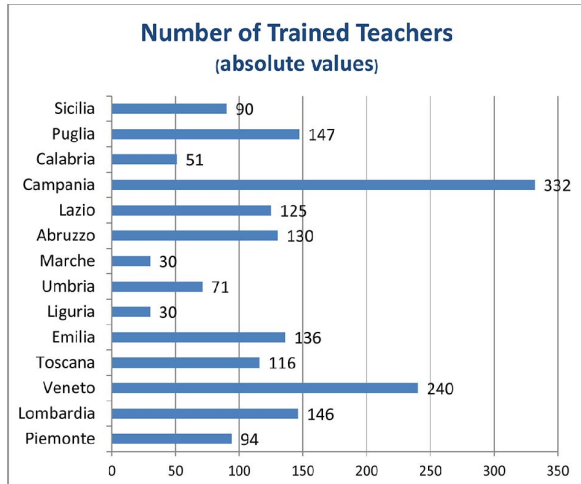


Fig. 5. Statistics of the distribution of teachers in training in the Italian regions.

The average age of Italian teachers is 51 years old: it is high and often source of worry, especially when they realise that they will have to confront with students, who are more familiar with new technologies. To their support, during and after the online training, it is offered a strong tutoring conducted by PhD students appropriately trained. In particular, the choice of tutors aged 22-25 years old is well appreciated by teachers, because the age gap is shorter than the one existing with their students, but at the same time dealing with young tutors is less intimidating than University professors. Fig. 6 shows a moment of a web tutoring using Adobe Connect: a tutor is showing some Maple commands to the online teachers by sharing the desktop.

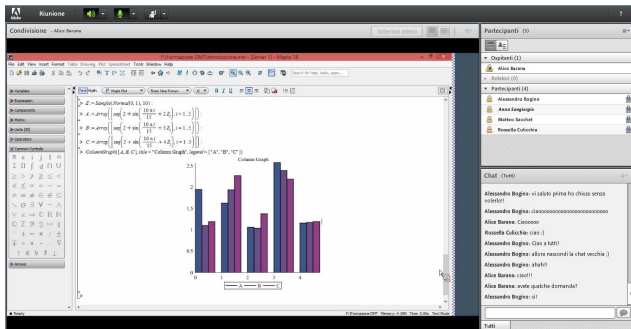


Fig. 6. Web tutoring with Adobe Connect.

The model of teacher training has been accommodated by MIUR in collaboration with University of Turin, in particular with the Department of Mathematics and the Department of Computer Science, which for years have been working together on the issues of e-learning, permanent training, lifelong learning of students and adults in general. This training format, which resulted really effective, is adopted by University for the permanent training of its administrative staff and to deliver updating courses to communities of graduated experts operating in the working word.

## VII. PP&S INSIDE EUROPEAN PROJECT SMART

Since October 2014 PP&S is part of the European Erasmus Plus initiative with the SMART (Science and Mathematics Advanced Research for good Teaching) project, whose principal purpose is to promote the acquisition of professional competences in support of the innovation of the initial and continuous training system for teachers of Maths, Physics and Science, in a European confront on methods and processes. The Project was proposed by the "Carlo Anti" School Institution in cooperation with an international partnership composed of other vocational schools, universities and representatives of the job world of five countries: Italy, Sweden, Germany, Hungary and the Netherlands. Other specific aims of the project are:

- to improve the professional competences and to support innovation in the teachers' training system through pedagogical solutions and innovative practices based on the new computer and multimedia technologies;
- to provide tools and methodologies capable to facilitate the acquisition of STEM (Science, Technology, Engineering, Mathematics) skills - mathematical competence and basic competences in science and technology - through discussion and sharing with European partners and by introducing advanced technological tools in the teaching of Mathematics and Science to support learning;
- to complement the action of classroom teaching with e-learning activities by creating co-operative learning communities both for students and teachers;
- to develop skills which can be used in order to contribute to a cohesive society, in particular to increase opportunities for learning mobility and through strengthened cooperation between the world of education and training and the world of work, formulating and solving complex problems autonomously, consciously and constructively so that students could be highly motivated in the study of Mathematics.

Through the European Project SMART, PP&S will work on a definition of common educational models and on open online courses for teachers' training.

## VIII. CONCLUSION

For the next years the purpose of the PP&S is to invest the whole educational system, which means to involve all Maths and Computer Science Italian teachers and all Italian students.

A second development consists of introducing in all schools, especially in scientific high schools, Computer Science as a curricular subject in the first two years, and make sure that Maths and Computer Science teachers work in stricter cooperation. To this purpose, an experimental program, funded by the European Social Fund (ESF), has been started in a "pilot" school in Turin. It aims to plan the curricula of the firsts two years with didactic material, lessons and activities, in synergy with the PP&S project, [2].

Learning paths for the third and fourth year of high school have already been prepared, those for the fifth, first and second year are in progress. One aspiration for the next years is to make possible that all the didactic materials produced in interim and on its completion will be open accessible to everyone. PP&S intends to promote free access to all the resources through the web portal and the interactive platform, with no limitation for the usage of materials. The production of innovative teaching modules for secondary school students in Mathematics and the on line module for training teachers will be available to all High Schools.

A careful study on assessment and on the certification of competences reached at the end of high school is in progress. In particular the study is aimed to evaluate the development of basic and transversal skills, such as entrepreneurship and digital skills, using innovative and student-centred pedagogical approaches and developing appropriate assessment and certification methods based on competences.

We monitored and are monitoring all the activities of the Project through workshops and questionnaires directed to all the participants. We are also drawing comparisons between traditional teaching and teaching adopting the PP&S philosophy. It is also important to continue to work to create verticality of skills between the secondary school system and university, in order to make sure that there is a continuity in the preparation of students and to create a good connection between schools and the world of work.

Through SMART we hope that PP&S will work for the promotion of stronger coherence and transparency of national recognition tools, in order to ensure that skills and qualifications are easily recognized across borders.

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