Adaptive teaching supported by ICTs to reduce the school failure in the Project "Scuola dei Compiti"

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***Abstract*—Adaptive teaching consists in a teaching style aimed at overcoming inner differences among learners by providing them tailored ways to achieve outcomes according to their learning style, culture and needs. ICTs play an important role in supporting teachers with the adoption of adaptive strategies. Adaptive teaching acquires relevance in contexts of scholastic remediation and in reducing failures. The paper presents and discusses how adaptive teaching is used within "Scuola dei Compiti", a project proposed by the City of Turin (Italy) in collaboration with the University and the Polytechnic of Turin, aimed at reducing the drop-out rate and at enhancing scholastic success. University students help groups of 5-6 students aged 13-15 with their difficulties in the main subjects (Mathematics, Italian Language, Foreign Languages). Part of the Mathematics courses adopt a set of innovative computer based methodologies developed by the Department of Mathematics of the University of Turin, including a virtual learning environment integrated with an advanced computing environment, an automatic assessment system and a web-conference tool, which support adaptive teaching. The project has involved over 7500 students in the last 5 years; the results achieved, discussed in the paper, show the effectiveness of these methodologies with respect to traditional teaching methods.**

Keywords—adaptive teaching; advanced computing environment; Mathematics education; reducing school failure; virtual learning environment

I. INTRODUCTION

If you happen to have a look at a school class, in whatever region and of whatever grade, you can notice how multicultural it is, compared with the schools that you attended. Since higher education is not a privilege for rich people anymore, and since the search for a job has gone beyond regional boundaries, schools are attended by boys and girls with different cultural backgrounds. If we add up individual differences in learning styles, attitudes and inclinations, it is clear that it is not easy for a teacher to lead all students to the same learning goal. Besides having a deep knowledge of the subject, a teacher is also asked to [1] understand each student's strengths and difficulties, to find the suitable way to share knowledge with each one and to manage one entire class of different students, trying to convey meanings in the best way to all the students at the same time.

This process lies under the definition of "adaptive teaching": according to Borich, it means to *"apply different instructional strategies to different groups of learners so the natural diversity prevailing in the classroom does not prevent any learner from achieving success"* [2]. The learning environment created when such methods are successfully applied is tailored to assure the best learning experience for every student. This insight has acquired particular importance since the aim of instruction has been moving from the delivery of static knowledge to the development of contextualized competencies. The definition of "competence" indeed involves "personal aptitudes", which enable knowledge and skills to act appropriately in a particular situation or to solve a problem [3]. These being the European indications, national dispositions on educational matter must align with them, therefore a student-centered approach cannot be avoided at school.

The success of adaptive teaching techniques is broadly documented in literature [4] [5]; results become even more relevant when they are applied to small groups of students with the aim to help them with their difficulties [6]: individual attention is a key factor to prevent failures, promoting self-awareness, give every student a chance to demonstrate his strengths and understand his weaknesses. Adaptive teaching is supported by the use of technologies, as some automatic processes can successfully replace the physical presence of a teacher in the proposal of different learning paths, with feedback and suggestions that a teacher could not offer simultaneously to several different students.

This paper presents and discusses a remarkable experience where adaptive teaching is applied to help small groups of students improve their scholastic results, within the Project "Scuola dei Compiti" (which means "The School of Homework"). In the last five years the project has involved about 40 schools of the City of Turin and reached about 7500 students, who had difficulties in Mathematics, Italian and Foreign Languages. Part of the Mathematics courses have been

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held in an experimental manner, using an integrated e-learning platform, which supported the application of adaptive teaching strategies. In the following sections the aims of the project and the methodologies adopted especially in experimental Mathematics activities are presented, the process of evaluation and the results obtained are shown in detail, giving proof that, in remedial classes, adaptive teaching strategies supported by ICTs have been effective for reducing failure at school and the drop-out rate.

II. STATE OF ART

Since the 1960s the education field of study has showed an interest in individuals and in individual differences. Different learners show different aptitudes toward learning or they respond to different forms of instructions in different ways [7], which may change over time. As the instructional strategies affect the learning outcomes [8], they should be adjusted accordingly with the progress of the students, which need to be monitored in real time. Hence the idea of technology based adaptive teaching [9]. From this assumption, many automatic systems have been developed for the online control of learning. They are based on the collection of the learner's data through assessment and analysis of activities, in order to provide personalized paths with materials and activities which best meet his needs and dispositions [10]. The most relevant effects of adaptive teaching methodologies collected in the literature include: more engaging, relevant, and interesting lessons for all the learners; comfortable learning environment; learners do not worry about saying something wrong; mistakes are necessary to inform the teacher about how to adjust the strategy; learners take increasing responsibility for their own growth [11]. On one side, the use of ICTs boosts all these factors [12]; on the other side, they are particularly relevant in contexts of tutoring as key points for the promotion of success at school [6].

The project Scuola dei Compiti is inserted in a context of tutoring and education aimed at reducing failures; the project itself has been studied in a few researches which mainly show the good effects of peer tutoring in fostering the student motivation, a key factor in prevention from failures [13]. The methodologies used in experimental Math courses, presented in other research works and here related to adaptive tutoring, follow the same trend indicated by the Italian Ministry of Education and applied in the national project Problem Posing and Solving [14] [15] [16]. They have also been the focus of an international discussion in the Erasmus+ Project SMART (Science and Math Advanced Research for good Teaching) [17].

III. THE PROJECT "SCUOLA DEI COMPITI"

In 2012 the Department for Education Policies of the City of Turin conceived a new project, "Scuola dei Compiti", aimed at reducing the drop-out rate. The project is carried out on students of the last year of the lower secondary school and of the first year of the upper secondary school (mainly technical and vocational institutes) who have low grades in fundamental subjects (Italian, Math and Foreign Languages) arguing that they would be more at risk of abandoning the studies after compulsory schooling and before graduation. The chosen target is thus students aged between 13 and 15, not well motivated or with some gaps in their basic knowledge, many of whom are not Italian, live in poorer suburbs and have little familial support for their studies. The project has been proposed in partnership with the University of Turin and the Polytechnic of Turin, and financed directly by the City of Turin and partly by Fondazione per la Scuola della Compagnia di San Paolo. The first edition of Scuola dei Compiti took place in Spring 2013; after its good results the project has been repeated each year, two editions per year (Autumn and Spring, according to the Italian school system) until the current scholastic year.

A. Organization of the project

Students with low grades in Italian Language, Mathematics or Foreign Languages (between 4 and 5 out of 10) can participate in afternoon courses at their school, held by university students (tutors) under the supervision of retired teachers. The courses can be attended by small groups of not more than 5 or 6 students, in order to guarantee the maximum attention of the tutor towards each of them. Courses last 9 weeks and include one or two weekly lessons of two hours each. During the courses tutors help students with their homework, and to revise and understand the topics studied in the morning. Their main goal is to favor student motivation for the subject in a friendlier environment.

In the first edition 115 courses were activated in 19 schools, involving about 50 tutors and 500 students. Within two years these numbers nearly doubled and progressively increased until the present as shown in Fig. 1 (data are available until last edition, Spring 2016). In these first four years over 6300 students attended the courses of Scuola dei Compiti (this number reaches 7500 including the current edition) employing over 600 tutors.

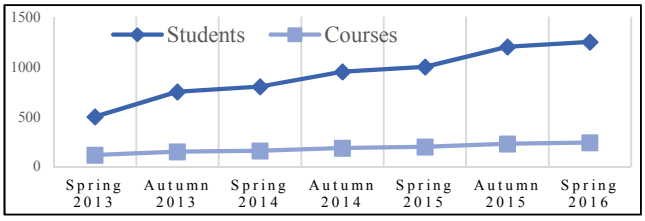

Fig. 1. Students and courses in the project over the editions.

B. Traditional and experimental courses

Since the first edition two kinds of Math courses have been activated: traditional (TM) and experimental (EM). While in TM courses tutors just help students with their homework in paper and pencil fashion, in EM they use innovative technology-based learning methodologies and take place in the school laboratory.

IV. METHODOLOGIES

A. Methodologies designed for experimental Math courses

The EM courses use a set of innovative methodologies and technologies for teaching and learning scientific disciplines, developed at the departments of Mathematics and of Computer Science of the University of Turin and specifically customized to reduce the school failure [18] [19].

1) Problem Posing and Problem Solving

The first visible typical trait of students attending Scuola dei Compiti is their poor interest for the subject. To remedy this, an

effective tutor should help them discover a passion for Mathematics or understood the general meaning of the topics studied. Learning Mathematics in a problem solving environment becomes fundamental, since it provides interesting starting points for introducing otherwise unwelcome themes, it helps students to link abstract concepts to real situations and to deeply understand their meaning, lastly it confers a general sense at a subject that is too often thought to be useless in real life. Tutors use problem posing and solving as incipits for their lessons; the challenge is to find the most attractive pretexts for their students and that means paying attention to their hobbies, vocations and passions.

2) Advanced Computing Environment

An ACE is one of the most innovative systems for dealing with Mathematics. In the Project Scuola dei Compiti the ACE Maple is adopted. Students can use Maple to perform numeric and symbolic calculations and thus focus on the solving process instead of heavy computations. They can display graphically the algebraic solutions of their problems and get geometric visualizations in two and three dimensions, even animated. Several interactive features are already implemented within the system or can be prepared by the tutors: students can change parameters and observe what happens, explore new concepts and play with Mathematics.

3) Virtual Learning Environment

Students of EM courses have access to a Virtual Learning Environment (VLE), available at the web address http://scuoladeicompiti.i-learn.unito.it. It is a high-performance and high-availability Moodle platform developed by the Department of Computer Science of the University of Turin and integrated with other systems for synchronous and asynchronous tutoring. Students can connect from home and log to the course dedicated to their school. There they find all the resources and activities prepared and made available by their tutors: discussion forums, chats, interactive and collaborative activities. The Moodle integration with MapleNet makes interactive material created with Maple available online to students, so that they can use the interactive files also with their tablets or smartphones and they do not need to download Maple on their personal computers. The platform is continuously maintained and monitored, to ensure a user experience as smooth as possible. This VLE can be easily adapted by tutors for their students, not only by adding pictures, videos or other features which may attract their attention, but also creating adaptive paths of materials and activities. The completion of the activities can be tracked, and access conditions, based on activity completion or on evaluations, can be added to all resources, so that users visualize resources suitable for their level. Moodle also has a gradebook, which is useful for tutors to keep control of the class; information about students' logs and activity completion are also available to students for the same purpose. The VLE has been designed to be accessible through several technologies, such as mobile supports and screen readers for the blind or partially-sighted. In addition, it utilizes a high-readibility font, EasyReading, certified for Dyslexia.

4) Automatic Assessment System

The VLE used is integrated with an Automatic Assessment System (AAS), Maple TA, specific for Math. Empowered with the Maple engine, Maple TA is able to recognize equations and formulas even in open answers and to evaluate their mathematical equivalence to the correct answer. Questions are algorithm based: this not only means that random variables can be inserted, but also that all Maple commands are available to build the question texts, to compute the answers, to add graphics and feedback. After completing an assignment, immediate feedback is returned to students, and the details on the given answers remain available online both for teachers and for students. The Moodle gradebook is integrated with Maple TA, so that it is possible to monitor the progress of students and to reveal their difficulties [20]. This AAS also supports the creation of adaptive questions and adaptive assignments. Adaptive questions are composed of sections that are shown to the student depending on the previous given answers. The model of adaptive question designed for remedial teaching by the Department of Mathematics consists of a problem posed in a first section, where the solution is directly asked. Students who answer correctly receive a positive feedback and complete the question. Those who give the wrong answer do not receive a negative feedback and are led to the solution step-by-step, one small question at a time. The correct answer is shown after each step so that it can be used for the following one. Adaptive assignments are composed of questions grouped by their difficulty level. Students stay in one level until they answer correctly to a minimum number of questions; afterward they are promoted to the upper level and they are asked more difficult questions. After a set number of mistakes they drop to the lowest level [21]. Tutors prepare an assignment after every lesson, so that students can practice at home; Maple TA is also used in class to check the understanding of the topic explained.

B. Web conference tool for synchronous tutoring

In addition to the lessons in the laboratory, EM course attendees have their tutor available online for a one-hour weekly web-meeting. It takes place in the VLE through the integration with Adobe Connect, a web conference tool which enables the interaction among participant through voice, chat and screen-sharing. Just like all the other tools for asynchronous and adaptive tutoring available in the platform, the web meeting offers students a further chance to meet their tutor and clarify the doubts that emerged when studying at home.

C. Evaluation of the project

The project Scuola dei Compiti has been monitored through periodic surveys at the end of every edition. The survey includes, for each student: personal details; questions for the student about his relationship with the subject before and after attending the course; a section for the tutor, asked to evaluate the student's progress, the strategies adopted and their efficacy; a section for the school teacher, asked to evaluate the changes observed in the students at school after attending the course and its utility; the student's average grade before the course and the grade of the first assignment after the course; for attendees of the experimental courses, additional questions are asked about the efficacy of the innovative methodologies. Progress is examined not only in terms of understanding but also in terms of self-awareness and attitude towards the subject. All answers are expressed in a Likert scale from 1 to 5, where 1 is the lowest and 5 the highest value.

D. Students

As indicated by by the questionnaires, when enrolling to the courses students show low levels of motivation and self-consciousness of their capabilities (both evaluations according to the tutors are on average 2.5 with the s. d. of 0.8). They do not show excessive poor learning skills, measured with the average value of 2.8 by the tutors (s. d.: 0.8), and with a stricter 2.4 by their teachers (s. d.: 0.7). According to the tutors' frequent descriptions, classes are multicultural and students often have different teachers and different topics to revise. That means that tutors need to know every student in person and tailor their teaching strategy on each of them. This is not unrealistic, given the small size of the groups and the small age difference. Furthermore this is what tutors actually do, as reported by their responses to the question "what teaching strategy revealed to be the most efficient?" – where they differ from student to student.

E. Tutors

The tutors are university students who have the chance to teach in a particular context the subject of their study. They are generally interested in teaching and learning. Tutors follow a specific training before starting their work: it consists basically of a metacognitive reflection on their role; tutors of the experimental courses have an additional training on the use of the technologies and digital methodologies for learning. Their key strengths, highlighted by the results of their questionnaire, are the deep knowledge and the greater passion for the subject, their willingness to take the challenge and their young age, leading to the creation of a comfortable learning environment.

V. Adaptive teaching in "Scuola dei Compiti"

The learning environment created in the afternoon courses is a particular setting where adaptive teaching is naturally and successfully applied. In order to accomplish the objectives of the project and to help students succeed in the discipline, tutors should, above all, identify and understand their difficulties, weakness and strengths. Keeping that in mind, they need to choose the best strategy to approach every student, capture their interest, explain all the points of the program in multiple ways so that everyone can understand, and lastly maintain reliability and authority in order to make the whole class listen to them. Once the strategy has been outlined, tutors should keep the progresses under control and be ready to change when necessary. With the traditional communication tools, brilliant tutors can obtain very good results. The methodologies and tools designed for the EM courses provide additional aids to the tutors to facilitate their task and succeed in their work.

A. Adaptive teaching in experimental Mathematics courses.

Working on a VLE offers an additional help to students who can interact with their classmates and with the tutor also outside school: the tutor's aid, well organized activities and automatically graded additional exercises can create the familial support that most of the students attending Scuola dei Compiti lack. 69% of students who used the platform declare – in an open answer - that it is particularly useful because they can get help even when they are studying at home. From the tutors' point of view, the VLE offers additional chances to get to know their students better not only during synchronous and asynchronous tutorings, but also from the personal profiles that users can modify. One tutor, for instance, noticed that some of his students set as personal images some logos of their favorite football teams, so he decided to use the football championship as a pretext to explain probability in the following lesson. It occurred to him to create a questionnaire for discovering other interests and passions of his students and he used the collected data for problem posing.

According to several experts, adaptive teaching must be rooted in assessment and the use of an AAS increases its effects [11]. Students can indeed try the exercises they need, when they need, at their own pace. This facilitates the tutor's management of the class: all students work actively at the same time, everyone is involved in his assignments, automatically guided by the system. "*Some difficult exercises could be solved well and quickly, rather than taking long and doing them badly*" explains one student, asked about the advantages of Maple TA compared with traditional methodologies. Through adaptive questions they learn a method, receive partial credits and are motivated to keep studying. Algorithmic questions ask students to repeat the reasoning over different numbers, thus consolidating the learned processes. Automatic grading allows students to autonomously identify their difficulties and to select the doubts to ask. Tutors can thus answer mainly focused questions and clarify precise problems; from the analysis of the gradebook they can monitor progress and accordingly adjust the strategy adopted with each one.

The autonomy of students resulting from automatic grading is intended to fulfill a higher goal, going beyond the mere understanding of some difficult topic: the increase of self-consciousness, learning to learn, and involvement in their own progress. "*You can understand what you have to improve and how much mistakes are important*" states another student, clearly expressing the value that mistakes assume in the automatic formative assessment. Some tutors adopted the AAS to create competitions when they needed to raise the level of attention and engage students; others opted for peer tutoring activities and assigned questions to couples of students.

The ACE, if used according to the designed methodologies, becomes an instrument of personalized learning as well. The rapid capabilities of computation and graphic representation make it easy to explore all the possible ways to study and display mathematical concepts and all the possible solutions of a problem: the tutor just has to choose those that best meet the students' learning style [22]. Through accurate observations and suitable activities, the ACE also allows tutors to inquire about students' favorite learning style. For instance, a tutor says that Maple supported a lesson of space geometry by providing pictures of three-dimensional figures that should match students' mental representations. Questions asked to the students allowed her to investigate about their ability to create mental representations of geometry. Moreover, by using computers students can try new procedures with different parameters leaving the computations to Maple: they can focus on the method and understand the meaning. While each student explores autonomously and experiments mathematical concepts, the tutor monitors the class and finds new ways to repeat the topics to those who still have difficulties.

All these methodologies are suitable for students with learning disorders as well: dyscalculics will be unburdened by Maple of meaningless calculations, dysgraphics will take advantage of the computer aid for writing and dyslexics will find in the VLE suitable learning materials. More generally, the use of adaptive technologies, which, unlike humans, never get annoyed, even after repeated mistakes, and the adaptive strategies sought by tutors contribute to the creation of a relaxed environment where also anxious students can feel comfortable and learn better [19].

All the EM tutors filled a specific questionnaire, which asked them to reflect about how these methodologies helped them activate adaptive strategies in their classes. The usefulness of the VLE for synchronous and asynchronous tutoring has been rated with an average 3.6 (s. d.: 1.0); the use of the ACE with 3.7 points (s. d.: 1.1) and its best feature has been identified in the graphical representations; the utility of the AAS reaches the average 4.0 (s. d.: 0.9) and its best features have been identified as rapidity and feedback (both for students and for teachers). The importance to have all these tools integrated in a unique learning environment has been rated with 4.6 (s. d.: 0.6). These results show that these methodologies have been considered strategic for tailoring the lessons to the students' needs.

B. Tutor training and support.

Tutors are thus in charge of a task that is not easy, in particular because they are not expert teachers. They need to be prepared to develop different strategies to meet the disposition of every student. Their training starts with a metacognitive reflection on their own character, their strengths and weaknesses which could influence their role and their work. The inner and personal reflection is carried on during the project through the request to complete a guided diary, intended to make difficulties emerge and to analyze reactions and solutions. Metacognitive support has been proven to be effective for trainings on adaptive teachings, as there do not exist lists of to-do solutions to know by heart, so every situation must be analyzed and confronted given the particularity of the student who is the protagonist [1]. In addition, in the same VLE, tutors are members of an online community where they can share experiences and suggestions. Discussions and exchange of practices allow them to learn from others a mile stone of adaptive teaching [22].

Tutors of EM also receive a specific training to the use of the learning technologies. The community of tutors of EM is particularly active in sharing materials and experiences, they are supported by a team of experts of these methodologies from the Department of Mathematics of the University.

VI. RESULTS AND DISCUSSION

Tutors' satisfaction of their work is undoubtedly a great result. However, what confers the effectiveness of the EM methodologies for adaptive teaching is the students' improvement at the end of the courses. Data are taken from the results of the questionnaires collected from Spring 2013 to Spring 2016 and filled by all the participants (6300 students). In particular, the results of EM attendees (1316 students) will be compared with TM ones (1937). The two groups do not show significant differences at the beginning of the project.

The effectiveness of Scuola dei Compiti is demonstrated by an increment of 0.70 in the students' grade after the end of the courses compared with their initial average in the subject. For EM this difference rises to 0.73, while for TM courses it stops at 0.68. If we consider also regularity in course attendance, we discover that EM students who participated to more than half of the lessons saw their results increased by 0.78, a value higher in a statistically significant way than the same increment for TM students, which remained approximately the same.

From the survey other interesting results about inner changes in student attitudes emerge. According to teachers at the end of the EM courses students show higher increments in metacognitive abilities such as motivation and self-awareness than TM students, as shown in Table I. After attending EM courses, 78% of students showed an improvement in their attitude towards Math according to the perception of their teachers, and 71% of them showed a visible increment in the participation to the lessons.

TABLE I. TEACHERS' EVALUATION ABOUT STUDENTS' PROGRESSES

		Before the courses		After the courses		Increment
		Average	**S. D.**	**Average**	**S. D.**	
Grade	**EM**	4.95	0.83	5.68	1.04	0.73
	TM	5.02	0.71	5.70	0.86	0.68
Self-awareness of their skills	**EM**	2.36	0.88	3.04	0.93	0.67
	TM	2.30	0.86	2.93	0.88	0.63
Capability to individuate the real cause of difficulties	**EM**	2.17	0.72	2.75	0.79	0.58
	TM	2.07	0.72	2.55	0.79	0.47

Interesting are also the results of students' self-evaluation, shown in Table II. EM students feel that the course helped them to overcome their difficulties with an average value of 3.17 (the same value for TM students is 3.07); 74% of TM students saw their grades increased after the course, while only 70% of the TM students said the same (statistically significant).

TABLE II. STUDENTS' SELF-EVALUATION ON THEIR PROGRESSES

		Before courses		After the courses		Increment
		Average	**S. D.**	**Average**	**S. D.**	
Interest towards the subject	**EM**	2.82	1.01	3.63	0.87	0.81
	TM	2.83	1.00	3.57	0.95	0.74
Self-awareness of their capability to succeed	**EM**	2.73	1.19	3.75	0.99	1.02
	TM	2.76	1.21	3.70	0.99	0.94
How the course help to overcome difficulties	**EM**			3.17	0.87	
	TM			3.07	0.84	

The students' awareness of having the skills and instruments to improve is an extraordinary result, from the perspective of prevention of failure at school and drop out. Students appreciated attending the experimental courses more than the traditional ones, under all points of view: the course organization, the timetables, the relationship with the tutor and, above all, the interesting materials. Details are shown in Table III. 71% of EM students state that they would repeat the course, while only 65% of TM students would do the same (statistically significant).

TABLE III. STUDENTS' EVALUATION OF THE COURSE

		Average	S. D.
Organization of the course	**EM**	3.65	0.77
	TM	3.52	0.85
Timetables	**EM**	3.40	0.91
	TM	3.33	0.95
Interesting materials	**EM**	3.68	0.89
	TM	3.52	0.91
Relationship with the tutor	**EM**	4.23	0.87
	TM	4.14	0.9

The learning environment created through ICTs is comfortable also according to the tutors. They answered with statistically significantly higher rates than their TM colleagues to questions about how their students received the activities, learned easily, remained attentive during lessons, collaborated with their classmates and got on well with the tutors. Data are reported in Table IV. In 66% of cases the use of an ACE during lessons captured the student attention, and students affirm that it has been useful on average with a 3.4 (0.9 s. d.), while the usefulness of the VLE has been rated with 3.5 points on average.

TABLE IV. TUTORS' EVALUATION OF THE COURSE

		Average	S. D.
Appreciation for the activities proposed	EM	3.34	0.92
	TM	3.17	0.93
Easiness in learning	EM	3.11	0.81
	TM	3.03	0.86
Attention during activities	EM	3.14	1.00
	TM	2.97	1.04
Collaborations with classmates	EM	3.51	0.92
	TM	3.37	0.92
Relationship with the tutor	EM	3.75	0.89
	TM	3.58	0.92
Taking on activities without being discouraged	EM	3.18	0.84
	TM	3.12	0.85

VII. CONCLUSIONS

In conclusion, the innovative digital methodologies designed for EM courses in Scuola dei Compiti facilitate tutors in applying adaptive teaching strategies with their students. The latter have hence more instruments to identify their main problems and to develop the most suitable learning method. These methodologies have been proved to be effective for overcoming difficulties, increasing results and re-motivating students to learn Mathematics. Recovering the motivation for learning is a fundamental key factor for reducing of failure at school. In the light of the results of the EM courses, the departments of Human Studies and of Foreign Languages of the University of Turin started similar researches aimed at designing digital methodologies for Italian Language, Foreign Languages and Latin. Experimental Latin and Italian courses has been activated within the project and reached similar results. Experimental English courses are intended to be activated in the next editions.

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