Assessment of individual and collaborative e-learning in problem solving activities

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Abstract

The assessment and certification of the achievement of learning objectives are a key point of actual discussion about e-learning. Progressive assessment is useful to inform students and teachers about personal and class advancements as well as engage and motivate them to complete a course. In order to be effective, assessment of online courses should include all fundamental aspects, from the development of individual skills to the interaction among participants.

This paper shows and discusses a method to assess the participation to an online course: this method is developed by the Department of Mathematics of the University of Turin within the project Digital Mate Training, funded by the Fondazione CRT. The project is focused on enhancing and strengthening mathematical problem solving competences by using an Advanced Computing Environment and it is carried out through an online training on a Moodle platform. Students' progresses are measured through Digital Mate Coins and Digital Mate Badges, a system of scores implemented on the platform which takes into account individual skills in problem solving, self-assessment activities and collaboration through asynchronous discussions.

The effectiveness of the model proposed is supported by the positive results and feedback in terms of satisfaction and achieved learning goals.

Keywords

Assessment of collaborative learning, assessment of e-learning, certification, problem solving, virtual learning environment.

Introduction

When designing an online course, where learning-by-doing methodologies are employed, special attention should be paid to the assessment of activities (Kearns, 2012). Grading students' performances during the course enables to enhance learning even in traditional education (Black & Wiliam, 1998); it acquires fundamental importance in a virtual learning environment, where students have to self-organize and regulate their own path. More specifically, (Hattie & Timperley, 2007):

- providing students with frequent and personalized feedback allows them to understand whether their efforts are correctly directed and to acknowledge their level of preparation;
- checking students' results enables teachers to keep track of the progress of the course and informs them about the effectiveness of the materials and activities they have proposed;
- formative assessment is one of the main sources of engagement and motivation to complete a course.

These advantages, typical also of traditional formative assessment, are particularly relevant in distance education, where the physical absence of the teacher requires the students to be much more responsible and committed in order to fulfill their course.

Another relevant issue related to the assessment of online activities is the certification of the competences achieved through the courses. Thence, they should include a form of final evaluation which takes into account all the efforts done by the students, their active participation, and the knowledge, skills and competences achieved.

This paper shows and discusses a system of assessment of online activities developed by the Department of Mathematics of the University of Turin within the project Digital Mate Training, whose main purpose is to promote, among high-school students, innovative methodologies for solving mathematical problems through the massive use of digital instruments for collaboration, new technologies and learning environments.

State of the art

Assessment in online courses is a delicate issue and matter of recent and wide discussion. Distance education differs from traditional one in several features: the main one is the asynchronous dialog and collaboration among participants. It has not an equivalent form in traditional classes and it is proved to be responsible of surprising results in learning. Online activities, such as synchronous and asynchronous discussions, peer cooperation and collaborative

writing, if well designed, allow the creation of communities of practice, which are able to boost the results of participants. The positive interaction can make the learning environment pleasant as well as enhance critical thinking (Lave, 1991). Communicating and collaborating in a virtual environment are also important skills which are useful and can be acquired through the participation to e-learning courses; they are at the same time a mean and a goal, therefore they must be adequately included in the assessment (Swan et al., 2006).

When the e-learning courses involve a large number of participants, it is convenient to implement automated assessment systems which limit the human interventions as much as possible; finding effective automated methods to evaluate interaction and collaboration is not so immediate and requires much attention in designing the activities (Chounta & Avouris, 2006).

Methodologies

An original way to assess online activities, collaboration and participation has been designed and experimented by the Department of Mathematics of the University of Turin within a project called "Digital Mate Training". The project has been funded by the Fondazione CRT and realized by the Department in the academic years 2014/2015 and 2015/2016 in collaboration with the ICT Services of the Computer Science Department. Both editions involved 150 classes of about 40 high-schools of Piemonte and Valle d'Aosta, for an amount of 3750 students, 120 teachers and 12 university tutors each year. The aim of the project is to develop and strengthen Mathematics and Computer Science skills through problem solving activities using the Advanced Computing Environment (ACE) Maple and a virtual learning environment (a Moodle platform dedicated to the project, whose website is http://digitalmatetraining.i-learn.unito.it). Each class receives a two-hour initial training on how to solve mathematical problems contextualized in the reality or in other scientific disciplines using an ACE (October – November). Then three students from every class are chosen and enrolled in the "online training" (December – March). On the Moodle platform the 450 students have access to one of the three courses dedicated to the three different involved classes (second, third and fourth year of high-school). Each of these courses presents a learning path aimed at training students to solve problems and to use an ACE. Every 10 days a new problem is published in each course; participants are asked to solve it using the ACE and to submit the files with their solutions to the tutors, who analyze and assess them. Students are also asked to fill a brief questionnaire which guides them to the self-assessment of their work according to the parameters chosen for grading the problems. When time for submission has expired, two solutions are published: one proposed by tutors and one chosen among the best files created by participants. Meanwhile, synchronous and asynchronous tools for tutoring and discussion

are activated within the courses: through forums participants can actively collaborate under the supervision of tutors; through the integration of Moodle with the web-conference tool Adobe Connect weekly interactive meetings conducted by tutors are dedicated at explaining the solution of the previous problem or illustrating some functionalities of the ACE.

After 100 days of training, participants challenge each other in a semi-final competition. Students are asked to solve one problem using the ACE and submit it within two hours. The authors of the 50 best solutions can participate to a 4-week advanced training on a dedicated Moodle course, and to the final competition. At the end, the best 8 participants will be awarded.

The online activities are designed according to the methodologies of problem posing and solving, learning by doing and collaborative learning. The Digital Mate Training allows the acquirement and development of competences in Mathematics, problem solving, team working and collaboration in a virtual environment as well as digital competences (Barana & Marchisio, 2016). The whole platform adopts the EasyReading (EasyReading), a high-legibility font, as a guarantee of the accessibility of its interface.

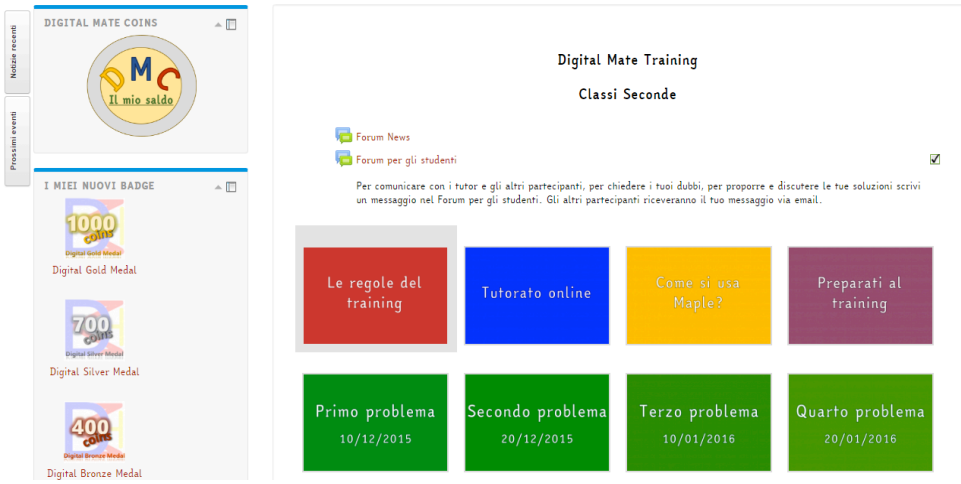

Figure 1 – Training course.

The problems' solutions worked out by the students are assessed by the tutors according to a rubric designed to evaluate the competences in Mathematics and problem solving using an ACE. More in details, the rubric is a table with 5 indicators (comprehension of the problematic situation, identification of a solving strategy, development of the solving process, argumentation, use of an ACE); for each indicator the tutor must identify in student's work the level of

competence achieved and assign a corresponding score. The rubric has been implemented in Moodle as grading method for the Assignments (the Moodle activity used for submissions). Problems are thus graded with a score from 1 to 100: this score is used to draw up students ranking and for choosing the winners.

In the first year of DMT project no systematic forms of progressive evaluation had been taken into account for the online training. Participants could submit their solutions on a weekly base and receive general feedback by tutors; they could also give and receive comments by their colleagues through the asynchronous forum discussions and during the synchronous web-conference tutorings. Only one problem, halfway through the online training, was graded according to the rubric as a trial of the competitions and an example of the grading system, but fundamentally a regular schedule of formative assessment was absent. This lack caused some difficulties to organizers as well, as they did not have clear feedback by students from which to draw conclusions about their preparation. At the end of the edition, student satisfaction was high (it was graded with an average value of 3.5 on a Likert scale from 1 to 5 in a final survey) but it was argued that there could be margins for improvement, especially as for active participation.

In the second year, some changes in the organization of the online training were proposed with the aim of enhancing engagement, quality of the experience of the training and achievement of the learning objectives. In particular, a system of formative assessment was implemented with the purpose of:

- motivating students to actively participate in the training,
- building indicators of the level achieved by students,
- providing information about students' participation.

To this purpose the so called "Digital Mate Coins" (DMC) have been proposed. It is a system of scores that students earn when they complete the online activities. The number of DMC earned for each activity completed is summarized in Table 1. DMC are also taken into account in the evaluation of the semifinal competition: to the grade achieved (up to 100 points assigned according to the rubric), up to 10 points are added based on the number of DMC earned during the online training.

Table 1 – DMC that earned by participants for each action in the training courses.

Action	DMC earned
ONE SUBMITTED SOLUTION TO PROBLEMS	from 1 to 100
ONE PERTINENT QUESTION POSTED IN THE FORUM	3
ONE ANSWER TO A QUESTION IN THE FORUM	5
ONE SELF-ASSESSMENT QUESTIONNAIRE	3
FINAL EVALUATION SURVEY	20
USEFULNESS OF SELF-ASSESSMENT	3.3

Digital Mate Coins consider three different components of the online training. The first one is the objective evaluation of the problem solving activity. It is performed by the tutors according to shared and clear criteria and it helps students to get used to the assessment methods which will be applied in the final competitions. Tutors' grades are followed by personalized feedback which could suggest different approaches to the problems and a better use of the ACE. DMC earned in this way measure the students' mathematical and informatics individual skills.

Moreover, they take into account self-assessment questionnaires, which are meant to make participants aware about the assessment criteria. Asking them to analyze their own work, they foster self-reflection and help to develop students' awareness of their achieved skills with respect to the course's expectations. This amount of DMC measures the development of students' metacognition (Akyol & Garrison, 2011).

The third important aspect included in DMC is collaboration among participants. As for each question posted in the forum they can earn 3 DMC, they are encouraged to make frequent use of the forum whenever they have a doubt; in addition, since each answer makes them earn 5 DMC, they dialogue and discuss among themselves with a minimal intervention of the tutors. To have an idea of the forum usage, during the second edition of DMT students made about 5500 interventions in the forums, 10 times the amount of posts written in the forums the previous year. This third part of DMC measures the communication and collaboration skills achieved during the training, which have positive impact on learning and on the whole experience.

From a technical point of view, DMC are simply evaluated from the course grades: forums, questionnaires and assignments are graded activities which are aggregated with the sum of grades. To make the reading of the amount of DMC earned more appealing and simple, an HTML block linked to the personal gradebook page has been added at one side of the Moodle course, as visible in Fig. 1; it shows an image of DMCs and the words "my wallet". The gradebook shows not only the grades but also the student's ranking, with the purpose of supporting gamification and helping students to acknowledge their level in relation to other participants. (Fig. 2)

A system of digital badges has also been linked to the DMC: students receive digital medals at the achievement of fixed thresholds of coins. In particular, a first encouraging badge is released at the achievement of 100 DMC, then the so called "Digital Bronze, Silver and Gold Medals" are released when students reach respectively 400, 700 and 1000 DMC. The role of badges is to set fixed levels and to notify students about their achievement. They appear on the students' Moodle personal page, as shown in Figure 3, and also in a block on the Moodle course page, as shown in Figure 1; fostering gamification and competitiveness, they are aimed at motivating the collection of DMC. In addition, they

are useful to rapidly inform teachers about the level achieved by participants (Gibson et al., 2015).

Elemento di valutazione	Valutazione	Classifica
Training per le classi seconde		
Totale corso	*1221,00*	*4/105*
Forum per gli studenti	307,00	6/105
Consegna il problema "Indice di Massa Corporea"	98,00	10/105
Consegna il problema "Media dei voti"	94,00	15/105
Consegna il problema "Talete e la piramide"	98,00	10/105
Consegna il problema "Pallanuoto"	99,00	5/105
Consegna il problema "Eredità"	91,00	9/105
Consegna il problema "Quanto freddo fa?"	100,00	1/105
Consegna il problema "Il recinto di casa"	97,00	2/105
Consegna il problema "Il nuovo stadio"	90,00	10/105
Consegna il problema "Dieta"	100,00	1/105
Autovalutati! - IMC	3,00	1/105
Autovalutati! - Media dei voti	3,00	1/105
Autovalutati! - Talete e la piramide	3,00	1/105

Figure 2 – Wallet of Digital Mate Coins

The semi-final competition selects 50 students who can have access to an advanced training and to the final competition. The advanced training is organized in a slightly different way. It lasts 4 weeks, one problem a week; students' works are assessed through peer evaluation, implemented with the Moodle "Workshop" activities. Students have 7 days to solve and submit one solution and 7 days to assess three solutions submitted by other three participants randomly chosen. The assessment is guided and follows the same parameters of the rubric: it is asked to choose a level (from 1 to 4) to the 5 indicators of the rubrics and to add a free comment. The final mark is automatically calculated. A new system of coins has been created for the advanced training: participants earn up to 100 Super Digital Mate Coins for their submitted solutions and up to

100 SuperDMC for the assessment of their colleagues' files, automatically computed on the base of how well they assessed the three assignments.

Peer evaluation allows students to make clear comparisons of their own preparation with other participants, to find new and different ideas to solve the problems and to use the ACE and to reflect on their own work. In addition, it frees teachers from the assessment of the students' files, which is a relevant advantage (Kern et al., 2003). Self-assessment is not implemented in the advanced training, since the role of developing metacognition is played by peer evaluation, through which students are lead to confront with the work of others. No additional points are given for forum discussions: as the finalists are generally the most brilliant and motivated students, there is no need to stimulate their participation. SuperDMCs were converted in up to 8 additional points for the final competition: in this way the ranking after the final competition depends only on skills of problem solving and use of an ACE. This choice is not unfair: the results discussed in the following paragraph clearly show that students who most actively collaborated and participated are the same who registered the best improvements and results in the semi-final competition.

Figure 3 – A user profile. Personal information has been removed.

Results and discussion

The introduction of the Digital Mate Coins in the online training had an effective impact on the results of the project and on the achievement of the goals. The system allowed participants and organizers to keep track of personal improvements and the evolution of the courses, with just a glance to the wallets. As the attribution of points is mainly automatic, it requires little work by tutors and organizers and the immediateness of updating of the gradings makes possible the real-time evaluation of activities. The highest result of such a system is the enhancement of learning: as DMC would add points to the score in the semi-final competition, students were motivated to collect all they could, and that means to complete most of the activities in the best way.

DMC system acted as a lever to make participants solve and submit problems by trying to do their best. The strict timeline had the same purpose: students could not submit their files after the time limits, so they were motivated to work regularly on the project and solve the problems in time. The effective improvements made by students are clear if we analyze their progressive grades obtained in the training problems: event though the level of difficulty increased, so did their average scores, which increased from 68/100 in the first problem to 81/100 in the last one with linear tendency ($R^2 = 0.55$).

A contribution to the general improvement in students' results comes from the self-assessment questionnaires. The reward to fill the self-evaluation given by the DMCs was effective: analyzing students' works, we noted that all of them were well discussed and contained a generalization, showing that students understood that these factors were highly taken into consideration in the rubric. The previous year resolutions were generally not as accurate and complete from these points of view.

However, the factor which had the most evident effects, was the assessment of collaboration. The incentive to discuss through forums stimulated students to consider the doubts and questions raised by the others and find possible solutions. This helped them to gain deeper understanding of the training problems and more experience on the use of the ACE. Students had also more chances to compare their work with that of other participants and to acknowledge their own level. It must be considered that students come from different schools from all over Piemonte and Valle d'Aosta, they do not know each other personally and they do not have any chance to collaborate or compare their work outside the platform. In addition, in a short period of time a lively community of practice has been created, making the experience within the project positive and constructive. Their interventions in the forums show that they felt part of a community and, even if the competitions were individual and students were actually rivals, they continued to help each other until the day before the semi-final competition. This shows that they learned how to collaborate, which is a high goal far beyond the focus of the project. The collaborative climate has also been indicated as the best feature in the online training by 70% of students in an open answer of a survey conducted among all the participants before the semi-final (other frequent answers were: the problems, the tutorings, using the ACE and collecting DMC).

The releases of the badges allow to instantly get the idea of the level reached by students. The number of releases of the first badge (100 DMC) gives an idea about the active participation to the courses (about 40% of the enrolled ones) while the other badges show the levels reached (the bronze medal has been achieved by 60% of active participants, the silver one by 40%, and the gold one – the most difficult to obtain - by 1% of them). These results are very satisfying if we consider that Digital Mate Training is an extra-curricular activity which requires a weekly dedication, not at all meaningless for high-school students.

The positive impact that DMC had on the students' performance and learning is proved by the other results of the survey handed out at the end of the online training. Table 2 summarizes data about engagement and perceived usefulness of the assessment activities are summarized. Answers are given in a Likert scale from 1 to 5, were 1 is the lowest grade and 5 is the highest. The results are graphically shown in Figure 4. At the end of the training 60% of participants declared to feel ready for the competition.

Table 2 – Evaluations extracted from the evaluation questionnaires.

Item	Average	Standard deviation
ENGAGEMENT IN COLLECTING DMC	3.9	1.0
ENGAGEMENT IN FORUM DISCUSSIONS	3.7	1.1
ENGAGEMENT IN ACHIEVING BADGES	3.4	1.3
USEFULNESS OF FORUM DISCUSSIONS	4.1	0.9
USEFULNESS OF THE TUTORS EVALUATIONS	3.9	0.9
USEFULNESS OF SELF-ASSESSMENT	3.3	1.1
APPRECIATION FOR THE TRAINING IN ITS WHOLE – 2015/2016	3.8	0.9
APPRECIATION FOR THE TRAINING IN ITS WHOLE – 2014/2015	3.5	1.1

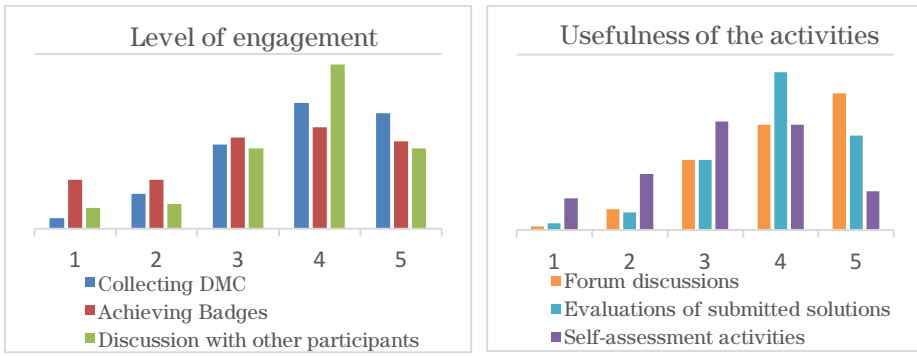

Figure 4 – Graphics of the level of engagement and usefulness perceived by students through the activities.

In order to show that the assessment system of the online training was effective we can compare the results of the semi-final competition of the two editions: the average score reached by participants in 2015/2016 is 12 points (out of 100) higher than that of the previous year. Given that the difficulty of the

problems was comparable, the grading methods and the modalities of the competitions remained unchanged and that participants to the second edition did not take part in the first one, such a difference must be attributed to the one difference between the two editions, that is the "Digital Mate Coins" assessment system, which helped students to have a better preparation.

For what concerns the advanced training, peer assessment has been appreciated by students, who liked evaluating their colleagues (average: 3.9, standard deviation: 1.1 in a Likert scale from 1 to 5) and found it useful for their preparation (average: 4.1, standard deviation: 0.9). In an open question 35% of students indicated that the peer evaluation was the best feature of the advanced training (of others, 35% indicated the higher level of difficulty of the problems, the remaining indicated tutorings, collaborations and the use of an ACE to solve problems). In particular, they appreciated the chance to examine the files produced by others, which allowed them to find new strategies to solve the problems and to use the ACE, but also to have a mean of comparison to self-assess their own work and preparation.

Conclusions

The positive results described above show how the assessment of activities can change the learning process in e-learning. Engagement, together with the creation of an online community affect the way participants perceive the whole experience: when it is positive, the percentage of course completion tends to increase and formative goals are reached more easily. These factors also influence the teacher's – or tutor's – satisfaction: thanks to feedback, s/he can better understand whether the didactic strategies are correctly working. When teachers are pleased with their own work, they rediscover their passion for teaching and thus give a positive contribution to the community, bringing benefits to learning (Hattie, 2009).

The possibility to collaborate, to see each other work and to discuss different ideas helps students to criticize their own results and enables metacognitive processes, which are fundamental for learning purposes and for the development of critical thinking and problem solving competences. Therefore, it is important that similar activities are included in online courses and that they affect the final evaluation.

The system of assessment implemented in the Digital Mate Training and measured in Digital Mate Coins allows to keep track of – and at the same time foster – engagement, participation, metacognition and the achievement of learning objectives. Participants have successfully used them during the course as a stimulus to complete the activities, whereas tutors have employed them to check progresses. What is more, they turned out to be perfect indica-

tors for teachers, since they informed them about their students' situation halfway through the project; they were taken into account in the final evaluation and lastly they could be used for purposes of certification of the course completion. A certificate of participation has been handed to all the active participants who took part in the semi-final competition, but there is the intention to enhance the process of certification to the project on the base of the DMC achieved, which could be used to differentiate the levels reached.

Seen the satisfying results achieved in the second edition of the project, ascribable to the introduction of progressive assessment, this method will be proposed again in the future editions of the DMT. The Department intends to develop and enhance it, in particular by deepening the study of assessment of collaboration in order to automatize the process and refine the indicators.

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