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Ten good reasons to adopt an automated formative assessment model for learning and teaching Mathematics and scientific disciplines

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Abstract

This paper will analyze an educational model for automated formative assessment developed at the Department of Mathematics of University of Turin for learning and teaching Mathematics and scientific disciplines. The model is provided through an automated grading system which, empowered by the engine of an advanced computing environment, allows the creation of algorithmic variables and open mathematical answers, recognized in all their equivalent forms.

The adoption of automated formative assessment brings many advantages to learning. Easily available assignments, immediate feedback, adaptivity, the chance of learning from mistakes turn assessment into a fundamental enhancement in education; the intrinsic "rigidity" of technology can also have positive results on students' path to knowledge. Automated assessment brings innovation into teaching: time saved in grading can be used to improve materials and activities, teachers easily get information about students' learning, they need to change their approach and to attend trainings; sharing and collaboration among teachers are facilitated.

Results obtained by the application of automated formative assessment in several class experiences are discussed and data about emerged satisfaction and criticisms are shown.

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Keywords: Advanced computing environment; automated formative assessment; e-assessment; e-learning; mathematics; virtual learning environment.

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1. Introduction

While Digital Natives, according to Prensky's prediction (Prensky, 2001), are conquering the technological universe, Digital Immigrants are committed to transforming all the facilities in order to satisfy the new necessities. E-learning and web-based technologies are spreading across the educational world, providing online courses for primary education, high schools, universities and professional training. With the birth of the first Massive Open Online Courses (MOOCs) offered by Harvard University in 2011, the global e-learning market reached $35.6 billion and the annual growth is estimated at 7.6% (Docebo, 2014). E-learning is widely considered as a leading factor for the development of education and economics, as it helps to deliver lifelong learning, to shorten the distance between instruction and work and to reduce costs. (SMEs & e-LEARNING Project, 2015). Within this framework, researches on innovative didactic methodologies have been stimulated, and has brought a true revolution in teaching and learning. The role of teacher has changed and different learning environments have been taken into account. Moreover, assessment has acquired relevance, since it fosters engagement and motivation, besides being able to raise scores and create standards. The University of Turin is breaking into this scenery developing an innovative model for formative assessment for Mathematics and scientific disciplines based on automated evaluation (Barana, Marchisio, & Rabellino, 2015). This paper will analyze and discuss the advantages and criticisms of this model and discussed and some relevant results of its application will be reported.

2. Tools for automated formative assessment

E-learning courses are based on the idea that students can access resources and activities at their own pace according their needs. Being forced to wait for the teacher's feedback after submitting an assignment is an obstacle to the independence of the students in organizing their own learning. A tool which automatically grades answers and provides individualized feedback is essential in the implementation of an e-learning or blended course. Within the online courses of the Department of Mathematics of the University of Turin the automated assessment system Maple T.A. has been adopted, due to its suitability for Mathematics and scientific disciplines. Thanks to the advanced computing environment, the engine behind the question execution, it is possible to create variables based on algorithms, random mathematical formulas and graphics. Open mathematical answers are accepted and grading algorithms can be implemented to verify if the given answer matches the correct one independently of the form: this allows to go beyond the multiple choice modality, develop different and complex cognitive processes, and test true skills and competences (Barana & Marchisio, 2015). Questions can be collected into assignments and proposed to students; online courses offered by the University of Turin are provided through the learning management system Moodle integrated with Maple T.A.: the automatically graded assignments can be mixed with the other activities of the courses. Maple T.A. gradebook, where all the students' results are recorded, is integrated with the Moodle one.

The Department of Mathematics has designed an application of Maple T.A. for the formative assessment and it has started to spread it. Through several projects and collaborations with schools and educational institutions at local, national and international level, the university is training numerous teachers to the use of this educational model and is supervising experiments in blended and e-learning courses.

3. Ten key strengths of the automated formative assessment model

An automated testing system undoubtedly fits the purpose of prognostic evaluation, detecting gaps in students' preparation before attending a course and checking if all the contents have been correctly acquired. It is able to return remarkable results when it is applied to the formative evaluation (Scriven, 1967) in order to perform an assessment not only for learning – in opposition to the assessment of learning – but also for teaching (Hattie & Yates, 2014). The designed model of automated formative assessment proposed by the University of Turin has the following features – listed below – which can be considered ten key strengths useful to enhance the teaching and learning of scientific disciplines. Let us start examining the point of view of students.

1. **Availability**. Automatically graded assignments on the Moodle courses are always available, as far as the teacher states they are: students can attempt assignments wherever they are, whenever they feel ready for - or in need of - exercises. Policies of tests can be easily edited. For example, it is possible to add time limits to the availability of the tests: this could be particularly helpful for young learners which still have to find the study method. For expert learners it is advisable to allow multiple attempts without time restrictions, to let them free to organize their learning schedule. Accessing learning from digital technologies is much appreciated by nowadays students, used to handling computers and tablets. Moreover, it is also useful for the developments of their digital competences and their critical use of the web.
2. **Immediate feedback**. Few seconds after the submission of a test students visualize their score, the corrections and the comments about their answers. Several researches (Luik, 2007) show that feedback plays a major role in formative assessment: the way it informs students about their performance has a great influence on future improvements. A prompt feedback is a key feature in questions designed for learning, as it allows students to realize if they understood and assimilated the contents of the course during the learning process. Teachers should insert in their feedback a link to the resources presented in the course where students can find how to solve the exercise or the problem. Thanks to the integration of Moodle with Maple T.A., the virtual environment for learning, assessing and revising is unique: as a consequence, dispersion, dangerous for learning, is reduced (Hattie & Timperley, 2007).
3. **Adaptivity.** According to several studies (Hattie, 2009), feedback is really effective when it rapidly informs about the correctness of the answer, when it is synthetic (otherwise students tend not read it), specific for the given response and, above all, when it guides students to the solution through an active process. We propose a meaningful way to provide automatic active feedback to students who have difficulties to solve problems through "adaptive questions", which is made possible by the adaptive functionality of Maple T.A. Our model of adaptive question consists in 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. Consequently, students discouraged by first attempt failure, have a second chance where they are asked to perform a simpler reasoning. In this way they learn a method, receive partial credits and are motivated to keep studying.
4. **Learning from mistakes.** Algorithmic questions and random-based questions can be repeated many times: they maintain their structure but changes in values. If students fail the first attempt, after the revision they can try the questions again but are forced to repeat the reasoning with different numbers until it has been mastered. Thus, mistakes can really acquire the value that Scriven theorized, becoming part of the learning process (Scriven, 1967).
5. **Respecting rules**. An intrinsic feature of technology is a sort of "rigidity". For instance, mathematical formulas must be written in a standard notation to be accepted. This aspect often annoys students, who lose marks for forgetting something they consider unmeaningful, but it is educative, for at least two reasons. Firstly, from a disciplinary point of view, it urges students to learn a standard notation: for example, in Italy the decimal separator is the comma, while Maple TA only accepts the dot. Students can thus get used to the English notation, which is more common in informatics. Secondly, from an educative perspective, students are induced to respect rules – which must have been previously shared and recalled in the question text. Consequently, the automated formative assessment could also be a good training for living in society and working in group.

The teaching process can also be positively influenced by the automated formative assessment, since, as Hattie states (Hattie, 2009), *"what works best for students is similar to what works best for teachers"*.

6. **Feedback** is a precious tool for teachers too, who are able to assess their own work through the students' performances. The gradebook offers them an immediate, ever-updated and easily accessible perspective of the level achieved by the class. Teachers should use that information to adapt their strategy and improve students' learning (Black & Wiliam, 1998).

7. A **change in the role of teachers** is encouraged. The adoption of a new different technology leads teachers to revise and innovate their teaching methods and to focus on useful tasks in order to enhance students' learning. This change of perspective is also reinforced by their participation in training courses, where it is their turn to be students again. Feeling closer to students, they are more likely to understand their difficulties.
8. **Teacher training**. Teachers received a traditional education and often do not feel much confident with technology. The introduction of digital tools in their didactics might not be as successful as desired if it is not supported by a suitable training program (Abrami, et al., 2006). Department of Mathematics promotes several training courses for teachers, both in presence and online, aimed at offering technical and methodological support on the use of automated evaluation (Barana, Brancaccio, Marchisio, & Pardini, 2015).
9. **Saving resources**. A natural advantage of automated grading is the drastic reduction of time for manual correction. Time and energy saved by teachers can be spent in the preparation of new questions, in the results analysis and in new activities design for their courses.
10. Algorithmic questions allow the creation of a theorically infinite **repository of questions**. They can be exported to other courses and shared among teachers. Sharing is one of the key ideas that Department promotes in the learning communities of teachers during their training. It is strategic foster the collaboration among teachers of the same institute, to motivate the adoption of one common set of didactic strategies (Ellerani, 2010), but also to stimulate discussions and exchanges of ideas among teachers from different institutes at local, national and international level. This could lead to the definition of common standards for learning and assessment (Brancaccio, Marchisio, Meneghini, & Pardini, 2015).

4. Achieved results and appreciation

The practice of automated formative assessment is very appreciated by students and teachers, as shown by the results of several surveys aimed at monitoring projects using this model.

Adaptive questions have been proposed with the aim of teaching students from a Foreign Language high school – who generally have little interest towards scientific subjects – to solve problems during a Physics course. Through online weekly assignments students were asked to solve problems with randomly generated data in the adaptive modality described above. The automated adaptive grading allowed them to autonomously learn the problem solving procedure, so that the class time could be dedicated to a more fruitful clarification of doubts. The best result, emerged by a questionnaire distributed at the end of the course, was the students' appreciation of the subject matter: it was the 31% higher than their general appreciation of physics (2.24 in a Likert scale from 1 to 5) and standard deviation reduced of 25%. Students liked the online quizzes (average: 4.46, standard deviation: 0.63); in particular, they appreciated their availability (average: 4.61, standard deviation.: 0.49), the immediate grading (average: 4.92, standard deviation: 0.27), multiple attempts (average: 4.77, standard deviation: 0.42), the guided solution of problems (average: 4.54, standard deviation: 0.5), randomly generated data in problems (average: 4.31, standard deviation: 0.72). Moreover, they think that these activities help them to better understand the topics studied (average: 4.0, standard deviation: 0.55).

Similar satisfying results have been achieved in a module of statistics during a Math course of a Scientific high school. Students appreciated the use of online activities (average: 4.26, standard deviation: 0.63), the availability of assignments (average: 4.52, standard deviation: 0.60), the immediate grading (average: 4.26, standard deviation: 0.91); they also considered the online activities as a help to better understand the contents (average: 4.11, standard deviation: 0.72).

Students' interest and satisfaction is one of the best goal for teachers, it gives them an input to overcome technical difficulties and to invest in professional development. The expectations of teachers about the use of automated formative assessment has been measured after a 12-hour training course involving 36 secondary school teachers of Mathematics and Science. Among the advantages of the adoption of Maple T.A. they pointed out the reduction of time in grading assignments (average: 3.75, standard deviation: 1.09 in a Likert scale from 1 to 5), an increase in the control over students' activities (average: 3.87, standard deviation: 0.78), the personalized feedback automatically provided (average: 4.03, standard deviation: 0.68), the huge amount of exercises that can be made available (average: 3.94, standard deviation: 0.70), the growth in students' awareness of their own abilities (average: 3.81, standard deviation: 0.58), the development of self-confidence (average: 3.59, standard deviation: 0.78), the possibility to perform an authentic formative assessment (average: 3.52, standard deviation: 0.86), increase in motivation (average: 3.59, standard deviation: 0.74), more objectivity in assessment (average: 3.75, standard deviation: 0.97). A growth in these values is expected after the experimentation in class.

Teachers who has already introduced automated assessment in their lessons are increasingly satisfied as they gain familiarity with such tools. The experiences of about 100 Italian teachers involved in a national project aimed to support the introduction of innovative methodologies in education (Palumbo & Zich, 2012) has been collected through a survey. Within their classes, they use a Moodle platform integrated with several tools – including an advanced computing environment and an automated assessment system - with their class in blended modality. Teachers who applied the automated formative assessment rated the level of appreciation of the innovative methodologies by students with an average value of 3.77 (standard deviation: 0.7) in a Likert scale from 1 to 5. 77% of them observed an increase in the level of learning after the introduction of the new methodologies and the 90% remarked that this approach was useful for the preparation of the final exams. Those values visibly decreased for teachers who did not adopt the automated formative assessment: the level of appreciation perceived by was 3.38 (standard deviation: 0.9), only the 59% of them observed an increase in the level of learning and only the 57% found the adopted tools useful for the preparation of the final exams.

5. Criticisms

The application of automated formative assessment has encountered some criticisms. One of these is the necessary use of a digital device and an internet connection, which are not available for the totality of the population, especially in poorest areas. Moreover, the use of technologies for educational purposes still faces some resistances especially by elderly teachers or less cultured families. Nonetheless, the diffusion of those tools is expected to show further development in the next future. Consequently, these kinds of oppositions should reduce over time.

Some disappointments coming from students deal with the little flexibility of the system in accepting the correct answers when compared with traditional grading. We know that Maple T.A. is able to recognize mathematical formulas in all their equivalent forms, provided that they are written in the correct form but students have difficulties to distinguish if a mistake is substantial or just formal. For example, if a result is required with a precision to the third digit, the correct number rounded to the second digit will be marked as incorrect. The answers input mode should be clearly described in the question text, and students get accustomed to reading and respecting instructions.

6. Future developments and conclusions

The model of automated formative assessment analyzed was designed to contribute to the diffusion of educational technologies which can improve the quality of teaching and learning, raise student's and teaching satisfaction and their educational relationship. The model is coherent with the current European trends which are promoting the spreading of e-learning. These methods will finally help Italy to catch up with the other European countries as far as digital education is concerned.

We are currently involved in innovative researches on how to improve this educational model and to propose it to teachers. It is likely that the level of appreciation will increase, and many criticisms will be reduced, if we keep on focusing on teachers and their training. A major concern is about providing significant examples which could adapt to anyone's needs, with the purpose of facilitating the work of teachers and obtaining even better results. We are also aimed at monitoring the application of adaptive assessment in classes. We have started a strong collaboration with Maple T.A. producer aimed at reinforcing the potentialities of the tool according to our needs and experiences.

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