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2019 IEEE 43rd Annual Computer Software and Applications Conference (COMPSAC)

COMPSAC 2019

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Empowering Engagement through Automatic Formative Assessment

Alice Barana
Department of Mathematics
University of Turin
Torino, Italy
0000-0001-9947-5580

Marina Marchisio
Department of Mathematics
University of Turin
Torino, Italy
0000-0003-1007-5404

Sergio Rabellino
Department of Computer Science
University of Turin
Torino, Italy
0000-0002-1757-2000

Abstract*—Engagement is one of the most powerful driving forces that moves learners forward in a learning experience. The effects of engagement are related with enjoyment in learning, good results and prevention to drop-outs. Technologies, and in particular automatic formative assessment, can positively influence engagement, as well as providing data to measure it. This paper discusses how computer-based activities with automatic formative assessment and interactive feedback can promote engagement in Mathematics at school level. After discussing a theoretical framework for defining and measuring engagement, the potentialities of activities with automatic formative assessment and interactive feedback designed according to a specific model are illustrated. The activities have been experimented with 299 students of grade 8 in Italy. Through questionnaires administered before and at the end of the experimentation and through data from the online platform, the effects of the online activities on student engagement is evaluated. The activities resulted particularly effective to increase the engagement level in students that had low attitudes toward Mathematics at the beginning of the project.

***Keywords*—Automatic Formative Assessment, Engagement, Interactive Feedback, Mathematics Education, Online Learning.**

I. Introduction

Engagement is one of the most powerful driving forces that moves learners forward in a learning experience. When students are engaged in a task, they tend to keep focused, to enact deep learning strategies and self-regulation, to achieve good results and even to get satisfaction and pleasure for their activity. More generally, encouraging and controlling engagement is an effective communication technique: the evolution of audience attention is a key factor that has to be taken into consideration when scheduling the duration not only of lessons, but also of presentations and performances. Going back to education, increasing engagement can be useful because engaged learners may enter a virtuous circle: when they obtain good results because of their work, their self-efficacy beliefs are intensified, and this keeps them engaged and makes them continue succeeding. On the other side, disengaged students who have difficulties in achieving good results may be trapped in a negative rather than positive loop, which hinders them from success [1]. Students coming from poor families or low socio-economic status might find it harder to be engaged in learning activities than students coming from medium-high social class, due to the little support they may find in their family, or to the greater difference they may perceive between their school and home environments [2]. These might be the root cause for drop-outs and early school leaving, and that is why supporting didactic projects, aimed at enhancing learning engagement especially for students with challenging backgrounds, is often a key strategy pursued by policymakers and institutions, interested in improving the quality of education over their territory.

In Mathematics, which is often considered a “hard science”, engagement is related to the development of strong aspirations for carrying on advanced studies in this field [1]. Since the development of Mathematical understanding is a crucial access key for workplace in the modern society, much attention to student engagement in Mathematics should be paid by teachers and educators from the very early school years.

Even more than for traditional schooling, engagement is a key point especially for online learning. In particular, it has been shown to be a strong predictor of MOOC retention [3]: studying solutions aimed at keeping users engaged is crucial to increase the completion rates, which are often very low due to the weak motivations of the enrolled students to complete the courses [4]. Technologies often support the engagement process: learning materials provided through gamification, simulation or interaction seem to be more effective than static resources in maintaining the users involved.

Technology also supports the teaching process: in virtual environments, unlike in traditional classrooms, the large amount of data registered and made available by the systems can provide

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useful information that help researchers understand the processes activated during learning situations, evaluate the effectiveness of teaching strategies and support teacher decisions.

This paper discusses how computer-based activities with automatic formative assessment and interactive feedback can promote engagement in Mathematics at school level. After discussing a theoretical framework for defining and measuring engagement, the potential of activities with automatic assessment designed according to a specific model are illustrated. Then, a didactic experiment conducted at grade 8 is presented. The methods for data collection and analysis are described in detail and the results are shown and discussed in the light of the theoretical framework.

II. Theoretical Framework

A. What is "engagement"?

Engagement is highly studied in the educational research field, and it is possible to find many different definitions and characterizations of this construct in literature. Some authors associate engagement with the level of attention [5] or with motivation [6]; others conceptualize it in terms of visible students' behavior which should reflect the way they engage with learning materials [7], in terms of intensity and quality of students' involvement in learning activities [8], or in terms of effort and investment students expend in the learning task [9]. In all these researches, active participation is a central theme for understanding engagement. In this paper we accept the definition given by Ng, Barlett and Elliott, who refer to engagement as "*students' dynamic participation and co-participation in recognition of opportunity and purpose in completing a specific learning task*" [1]. Peculiarity of this definition is the characterization of engagement as an interactive and purposive process; it allows to examine how it may change over time and vary according to situations and contexts. When students participate eagerly to a specific learning activity, they deploy appropriate strategies, regulate processes and monitor their actions. They feel happy, spend time and effort on the task, and show high levels of focus and concentration. However, these conditions may fluctuate: sometimes, students can fail to plan their actions, feel worried or not so willing to making efforts, or they can become distracted. Thus, engagement is not a mere personal property, but it is a set of actions undertaken by a person in a specific context where interactions with other people, artifacts and tools occur. Engagement has a fluctuant nature, this means that it depends on specific situations and it may change over time; it has a focal object, it is situational and malleable: it can be modified by changing task design, support or rules project [1]. The malleable nature of engagement means that it is possible to create repeated episodes eliciting engagement and so, in time, contribute to these students establishing positive stable beliefs and behaviors [10].

Despite the number of definitions, researches on engagement agree on the fact that it is a multidimensional construct [11]. The number and nature of the components may vary, but the main trend recognizes the three main components of student engagement identified by Fredricks, Blumenfeld and Paris: behavioral, emotional and cognitive [12].

Behavioral engagement concerns involvement in learning activities and it includes behaviors such as effort, persistence, attention, concentration, and completion of work [12]. Other definitions of behavioral engagement entail positive conduct, such as following rules, or participating to school-related activities [1]. When the focus is on homework, effort expenditure and timely completion are indicators of behavioral engagement. However, strict adherence to norms is not a good indicator for high-order thinking, enjoyment and interest: students could just keep quiet and pretend to pay attention, their level of interest being indeed very low [13].

Emotional engagement is understood as students' affective reactions in a classroom, which can vary from interest to boredom, from happiness to sadness, from satisfaction to anxiety. Interest and value for learning are important indicators of emotional engagement [12]. Emotional engagement is linked to several outcomes, such as improved persistence, learning achievements, but also liking school subjects and positive attitudes towards school [1].

Cognitive engagement is the mental investment people make in learning; it involves the use of deep strategies, self-regulation, openness to problem solving [12]. A high level of cognitive engagement can be detected when students enter into an interactive dialogue to generate new knowledge [7]. Students with high levels of cognitive engagement are less likely to give up their learning and more likely to keep engaged with school [1].

There are other dimensions that are considered by scholars in addition to these three. For instance, Appleton, Christenson and Furlong considered a four-component model having psychological engagement as fourth dimension [14]. Patrick, Ryan and Kaplan found that the social component is a strong factor of engagement [15]. Social engagement can be defined as the extent to which students collaborate and share responsibility in order to complete a task.

Ng, Barlett and Elliott make a distinction between these components, labelled as "indicators" of engagement, and the so called "facilitators" of engagement, which can be cognitive and social [1]. Among cognitive facilitators, the most acknowledged are:

- self-efficacy, that is the child's perceived ability to successfully complete a task within a specific domain or setting. Students who have developed a high sense of self-efficacy are more confident in their capacities and are more likely to get involved in tasks;
- achievement goals, that are students' perceived purposes to learn. There are two main types of achievement goals: mastery and performance goals. Mastery goals represent a focus on learning for the sake of improvement and understanding, whereas performance goals reflect students' attention to achievement; the former are more desirable than the latter, as they are linked to highest outcomes;
- autonomy, which refers to the choices that students can make freely during the learning process, and it is at the

core of the self-determinant theory for promoting engagement [6];

- interest, which involves both cognitive and emotional components and promotes and supports learning motivations.

Social facilitators refer to social conditions, interactions, and relationships that promote engagement; especially for adolescents, the influence that peers, teachers, family and the environment have on them is critical for their choices, behaviors and emotions [16].

This framework allows to classify research models based on engagement: in facilitators-focused models engagement is a desired outcome, while in outcome-focused models engagement is a mediator. In literature, the indicators of engagement are operationalized and translated into variables with the aim of measuring the level of engagement [11].

Low levels of engagement and low achievements are often related. In a study conducted by OECD after PISA 2012 survey it emerges that low performers in Mathematics, that are students who scored less than 2 in a 6-level scale, are less interested in Mathematics than better-performing students. They report low levels of perseverance, that is associated with work ethic. It seems that they do not devote enough time to homework, and that their effort in school related activities is not very productive, as it does not result in significative outcomes. Moreover, they tend to skip classes and school days and they show little sense of belonging at school [17]. Students with disadvantaged background are more likely low performers than top ones: socio-economic status has a great influence on school achievements as well as on attitudes and beliefs towards Mathematics [18].

B. Engagement and learning technologies

Students engagement in technology enhanced learning environments includes any interaction of the learner with instructors, peers or learning content through the use of digital technology; this can happen face to face or remotely, and the courses involved may be entirely online, blended, or face to face [19]. The potential of technologies can open up new ways in the research about engagement, contributing both to the measurement of the indicators and to the creation of facilitators of engagement.

When the focus is the detection of engagement, technologies offer many sources of data such as logs, registration of dialogues and answers that can be usefully integrated in the research [8]. Many authors agree that the mere number of logs is not a reliable indicator of behavioral engagement, if considered alone: the amount of time and actions spent on activities may vary largely among students according to their cognitive needs or to external factors. However, the data provided by automated systems can be combined in order to generate meaningful information about user experience [19].

Digital technologies are acknowledged to be powerful cognitive and social facilitators of engagement for several reasons: they enhance the possibilities to activate learning by doing or active learning strategies, which enable students to intellectually engage in the task [20], [21]; they increase the chances of interactions among peers and with the instructor [8]; they can facilitate self-regulation and adaptive learning through formative assessment [22], [23]; asynchronous activity enable learners to study at their own pace and to reflect on the learning process [24], [25]; in Mathematics and other STEM, they let you analyze real-world problems, thus making the subject interesting and relevant [10], [26].

C. Engagement and automatic formative assessment

If online learning can provide new tools for engaging students, its effect when combined with formative assessment should be promising. In fact, formative assessment strategies as prompting discussions, providing feedback that move learners forward, activating students and peers as protagonists of their learning and have, as their main consequence, that of acting on student engagement [27], [28].

Our research group proposed a model of automatic formative assessment for developing learning activities using an automatic assessment system particularly suitable for Mathematics; the model has been experimented using Moebius Assessment (formerly known as Maple TA) [29], a system based on the mathematical engine of Maple, which allows the definitions of mathematical formulas, graphics and algorithms running behind questions. In particular, it is possible to define grading codes aimed at evaluating mathematical answers for their mathematical meaning, and to create worksheets with several possibilities of interaction, step-by-step guided resolutions, and allow students to enter graphs or symbolic formulas [30], [31]. Fig. 1 shows one example of question created through Moebius Assessment: the geometrical figure was created through Maple's mathematical engine, the formula of the area is accepted if written in a mathematical correct form, even if different from the provided solution. Moreover, a preview of the graph of the function entered is provided to students before grading the answer, in order to enable them to self-assess their answer.

The model was shown to bring enhancement both to teaching and learning [23], [32], acting on competence and on self-regulation [33], [34]. According to this model, learning activities created with an adequate automatic assessment system should have the following features:

- Availability. Assignments are always available to students, who can attempt them at their own pace, without limitation in data, time and number of attempts.

- Algorithm-based questions and answers. Random values, parameters or formulas make questions, and the relative answers randomly change at every attempt. This can be realized through the implementation of algorithms running behind the questions. By algorithmic variables, different representational registers (words, numbers, symbols, tables, graphics, schemas) can be shown in questions and feedback.

- Open answers. The multiple choice modality is avoided whenever possible, to make room for open answers, where students are asked to respond in one of the different registers listed above.

- Immediate feedback. Results are computed in a few moments and they are shown to the students while they are still focused on the task.
- Interactive feedback. Right after answering one question the system can show whether it is correct and go through a step-by-step guided resolution which interactively shows a possible process for solving the task. Students who fail to answer autonomously to the main question are asked questions about prerequisites or simpler tasks. At each step, if they give the wrong answer, the correct one is shown to be used in the following step. They can gradually acquire the background and the processes that enable them to solve the initial problem. They earn partial credits for the correctness of their answer in the step-by-step process.
- Contextualization. Whenever possible, questions refer to real-world issues which can be relevant to students as well as for the discipline.

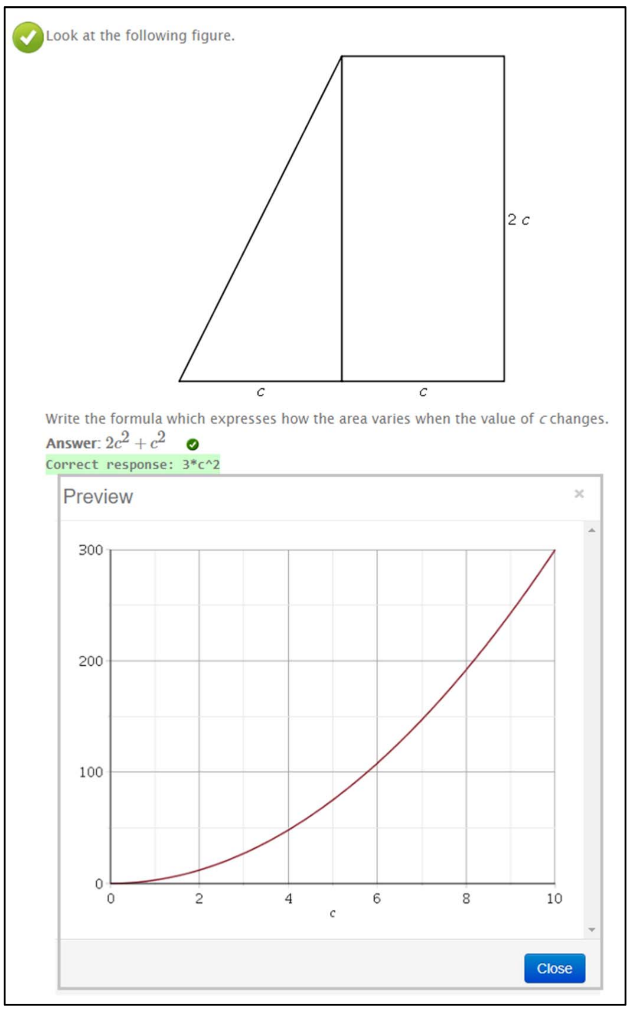

Fig. 1. Example of question created through Moebius Assessment

Fig. 2 shows one example of question created through Moebius Assessment according to the model previously described. Students can follow the step-by-step solution to learn how to apply the Pythagorean theorem to a real-world relevant situation. When students fail one answer to one of the sub-questions, the correct solution is given and it can be used in the following steps, so that students can individuate mistakes and correct them before proceeding. Numeric answers are accepted within a tolerance and formulas are matched with their mathematical meanings.

These types of activities should be cognitive facilitators of engagement: when students fail one answer, the interactive feedback activates them through the solving process making it possible to individuate the exact source of the mistake, thus acting on self-efficacy. Students can try the question again and find different parameters, so they have to autonomously repeat the solving process. Multiple attempts before showing the correct solution act on autonomy as well. The immediate feedback helps them focus on mistakes as a source of knowledge and to set mastery goals instead of performance goals. Lastly, real-world settings act on the student's interest for the subject, connecting abstract Mathematics to the real world [35], [36].

III. Research Hypothesis and Question

We can reasonably assume that students who, at the beginning of a learning path, show interest towards Mathematics and value their learning, who have high levels of self-efficacy, perseverance and openness to problem solving, can be easily engaged in learning activities of any kind. Therefore, we will focus on students at risk of disengagement in order to understand whether an experimental didactic intervention based on formative automatic assessment help students of 8^{th} grade to reengage in Mathematics.

IV. Research Method

In order to investigate the research question, a didactic experimentation has been designed and realized by our research group in the city of Turin (Italy) in 2017/2018 school-year. The experimentation involved 299 8^{th} grade students attending 6 different lower secondary schools in different areas of Turin. In particular, about half of the students belonged to low socio-economical class, while the other half to middle-high social class. The sample was composed by randomly selecting 13 classes from the 6 schools, which were entirely included in the project with their Mathematics teachers.

All the students filled in an initial questionnaire in November 2017, which aimed at investigating the initial level of students' attitude toward school and, more specifically, toward Mathematics. The questionnaire was administered online; it was composed of 35 Likert-scale questions inspired to PISA 2012 student questionnaire [37], with items about intrinsic and extrinsic motivation toward Mathematics, perceived control of success, Mathematics work ethic, Mathematics behavior, perseverance and openness to problem solving. Table 1 shows the items in the questionnaire. Intrinsic and extrinsic motivation are related to the emotional component of attitude toward Mathematics, as they entail the extent to which students are interested in and value Mathematics; work ethic, perseverance and Mathematics behavior are usually closely related and they express the initial behavioral component of student attitude; the perceived control of success and openness to problem solving are indicators of cognitive engagement. All items were on a 4-points Likert scale (strongly disagree/disagree/agree/strongly agree) except for the items on perseverance and openness to problem solving, where, through a 5-point Likert scale, a neutral position was allowed.

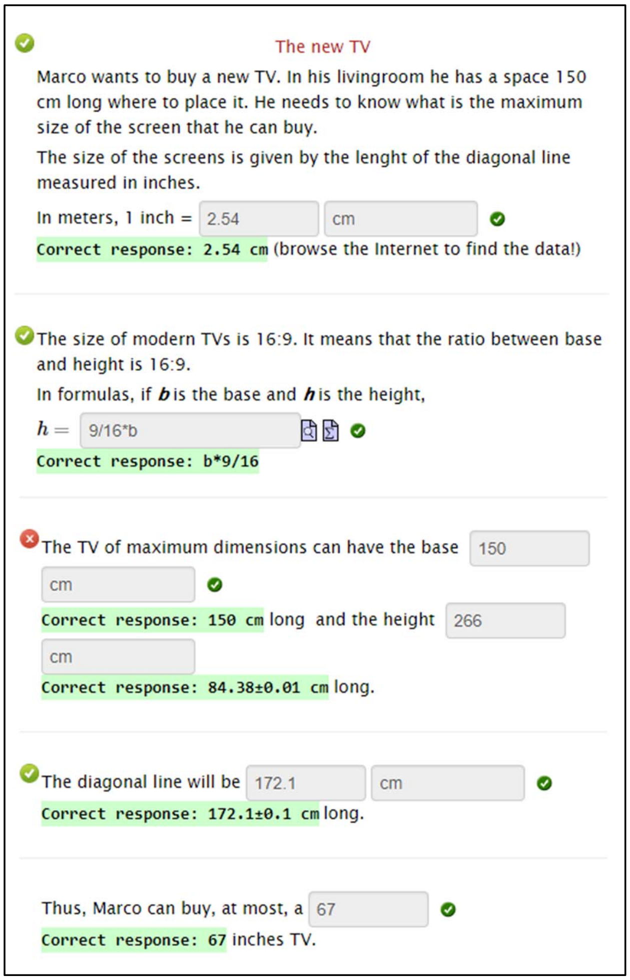

Fig. 2. Example of activity with automatic formative assessment and interactive feedback.

TABLE I. ITEMS OF THE INITIAL QUESTIONNAIRE

Subscale	Code	Items
Intrinsic motivation	QI1	I like lectures about Mathematics.
	QI2	I can't wait for Mathematics lessons
	QI3	I do Mathematics because I like it
	QI4	I am interested in the things that I learn in Mathematics
Extrinsic motivation	QI5	Making an effort in mathematics is worthy because it will help me in the job that I want to do later on
	QI6	Mathematics is an important subject for me because I need it for what I want to study later on
Perceived control of success	QI7	If I put enough effort, I can succeed in Mathematics
	QI8	It is completely my choice whether or not I do well in Mathematics
	QI9	Family demands or other problems prevent me from spending a lot of time for my Mathematics work
	QI10	If lessons were different, I would try harder in Mathematics
	QI11	Whether I study or not, I am bad at Mathematics
Mathematics work ethic	QI12	I finish my homework in time for mathematics class
	QI13	I work hard on my Mathematics homework
	QI14	I am prepared for my Mathematics exams
	QI15	I study hard for mathematics quizzes
	QI16	I keep studying until I understand Mathematics material
	QI17	I pay attention in Mathematics class
	QI18	I avoid distractions when I am studying mathematics
	QI19	I keep my Mathematics work well organized
Mathematics behavior	QI20	I talk about mathematics problems with my friends
	QI21	I help my friends with Mathematics
	QI22	I do Mathematics as an extracurricular activity
	QI23	I do Mathematics more than 2 hours a day outside of school
	QI24	I play chess
	QI25	I program computers
Perseverance	QI26	When confronted with a problem, I give up easily
	QI27	I put off difficult problems
	QI28	I remain interested in the tasks that I start
	QI29	I continue working on tasks until everything is perfect
	QI30	When confronted with a problem, I do more than what is expected from me
Openness to problem solving	QI31	I can handle a lot of information
	QI32	I am quick at understanding things
	QI33	I seek explanations for things
	QI34	I can easily link facts together
	QI35	I like to solve complex problems

Together with the questionnaire, they also completed a paper-based learning test with 10 multiple choice or open-ended items.

From December 2017 to June 2018 the classes with their teachers had access to an online course in a Moodle platform, populated with activities designed by the research group according to the model of formative automatic assessment. The online course covered the whole program for 8th grade Mathematics, ranging from negative numbers to solid geometry, from linear functions to equations. Materials and methodologies were shared with teachers through periodic focus groups in order to enable them to use the materials autonomously, in class through the Interactive White Board or in a computer lab, or to ask students to work on them as homework. A group of lessons in each class were held under the supervision of research group members.

Fig. 3 shows one example of activity with automatic formative assessment on solid geometry. The computation of the volume of a parallelepiped is applied to a real-world problem; students who fail to find the correct solution autonomously can use the interactive feedback in support of their reasoning. Partial grade is allowed for answers in the step-by-step process. Students, teachers and researchers had access to the students' answers that could be used as prompts for discussion or research.

At the end of the school year students were asked to complete a second paper-based learning test with questions about the topics covered in the online course and used by all the classes. Moreover, they were asked to fill a second online questionnaire conceived to evaluate the impact of automatic assessment activities on student engagement. In deep, questions focused on emotional aspects, such as interest, enjoyment and value for the learning activities, and on cognitive aspects, like cognitive and metacognitive processes enacted by the learning materials. The 15 items are reported in Table III; they are all 5-point Likert scale.

TABLE II. ITEMS OF THE FINAL QUESTIONNAIRE

Subscale	Code	Items
Emotional engagement	QF1	Having the materials available in every moment is useful
	QF2	The proposed problems are interesting
	QF3	The tests are useful to practice
	QF4	It is useful to visualize the correct answer after submitting a response.
	QF5	The online assignments are a valid help for studying
	QF6	Online assignments made me appreciate the topics studied more
Cognitive Engagement	QF7	Using the platform from home helped me identify the topics on which we worked in class
	QF8	The online tests helped me better understand the topics studied
	QF9	The online tests helped me understand if I understood the topics studied
	QF10	The immediate feedback helped me understand how the task should be solved
	QF11	Problems with step-by-step resolution helped me understand the solving process
	QF12	Online assignments helped me autonomously solve Mathematics exercises
	QF13	Online assignments helped me become more confident about my capabilities
	QF14	Online assignments helped me acknowledge my preparation
	QF15	When I gave an incorrect answer, I used to try the exercise again

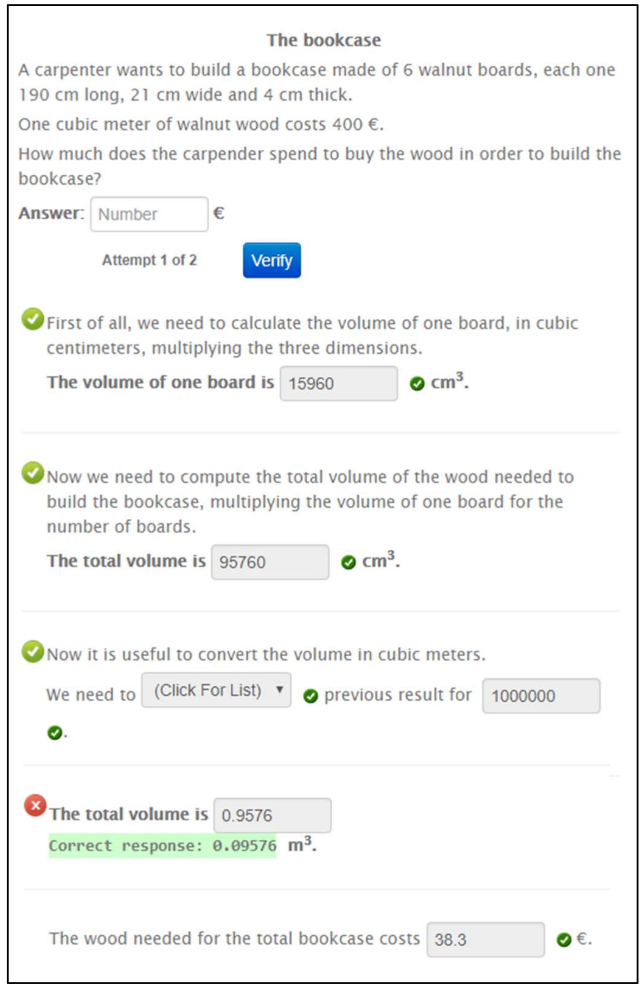

Fig. 3. Example of activity with automatic formative assessment proposed to the 8th grade students.

In order to evaluate the impact of the learning materials on student engagement, an initial profile of all the students has been depicted through their answers to the initial questions. Answers to QI9, QI10, QI11, QI26 and QI27 were reversed so that higher answers correspond to higher attitudes. Through factor analysis, answers were classified in three main sets, corresponding to emotional, behavioral and cognitive components of initial student attitudes; continual and categorical variables were defined as indicators of the initial level of student engagement in the three components.

Similarly, questions of the final questionnaire were split in two subscales, one related to emotional engagement and one related to cognitive engagement; two continuous variables were created as indicator of the final level of emotional and cognitive engagement. As behavioral indicator, the number of logs to any course activity, the number of submissions of automatically assessed assignments and the average rate of submission per assignment were collected and taken into consideration. The final level of engagement in each subscale was compared with the initial one; analyses were conducted using SPSS 25.

The reliability of all the questionnaires and the subscales were checked through Cronbach Alpha.

Students' socio-economic factor was determined using data from national surveys; the sample has been split in two categories: students from low social class and students from medium or high social class. The division broadly coincides with the division in schools: 4 out of 6 schools considered for the experimentation were mostly attended by students with low socio-economic status. The two schools attended by students from medium-high class participated to the project with more classes.

The learning data are not considered for this study. They are object of study in other papers, where they are compared with the results of a control group [34], [38].

V. Data Analysis and results

The initial questionnaire was answered by 278 out of 299 students (93%). Students who did not answer to the questionnaire were excluded from the sample. The reliability of the survey was checked through the Cronbach Alpha, which resulted sufficiently high (0.82). An initial factor analysis lead to the elimination of 5 variables: QI9, QI10, QI12, QI24 and QI25. As of the last two eliminated variables (playing chess and programming computers), they are probably not common actions for 8th grade students, so they didn't contribute effectively to the detection of Mathematics behavior. QI9 and QI10 ("Family demands or other problems prevent me from putting a lot of time into my Mathematics work" and "If lessons were different, I would try harder in Mathematics") probably concerned external factors compromising student success more than interior control of their actions. Although the effect of the teacher and the family environment may be important factors for learning and developing competences, they are usually not such as to impede school work and the achievement of success [17]. Regarding completing homework before classes (QI12), it has been noticed that the mere compliance with rules does not necessarily imply engagement: the homework can be finished just to avoid punishments (at grade 8 many teachers are usually very strict in demanding that homework is done on time) but this does not necessarily mean that behind the homework there is effort, and it could also be copied from classmates. The Cronbach Alpha computed on the remaining 30 items increased to 0.85. Factor analysis also evidenced a distinction between intrinsic and extrinsic motivation, which again is not in disagreement with literature: in the OECD volume "Low performing students" only intrinsic motivation is considered in analyzing the relation between drive and achievements [17]. Students who are intrinsically motivated engage in tasks because they simply enjoy them, and they are more likely to set mastery goals; on the other hand, students who are extrinsically motivated tend to set performance goals, that are less stable than mastery ones [39].

Through factor analysis, three standardized variables were created as linear function of students' answers to the remaining items: intrinsic motivation, which represent the emotional component of initial level of student engagement (EE_i); behavioral engagement (BE_i), composed by items on Mathematics work ethic from QI13 to QI19, items on Mathematics behavior from QI19 to QI23, and by all items of perseverance; cognitive engagement (CE_i), to which items QI7, QI8 and QI11 on perceived control of success and all items on openness to problem solving contribute.

The three categorical variables were built on the basis of the sum of students' answers to questions in the subscales. The variable had values 1, 2 or 3, meaning low, moderate high and high attitudes. In particular, for emotional engagement (EE_cat), the value of the sum of the answers to the four items could range from 4 to 16; a low level was defined for values equals or below 8; a medium-high level was defined for values ranging from 9 to 12 and high level for values higher than 12. For cognitive engagement (CE_cat) the cut-off values were 21 and 29 in a range from 8 to 37; for behavioral engagement (BE_cat) the cut-off values were 37 and 53 in a range from 16 to 69. Table II shows the distribution of students for each of the three variables. It is noticeable that students in the lowest levels of engagement are the minority.

TABLE III. Distribution of students for level of initial attitude

Initial engagement level	**Percentage of students**		
	Emotional Engagement (EE_cat)	***Cognitive Engagement (CE_cat)***	***Behavioral Engagement (BE_cat)***
Low level	8.3%	20.9%	15.0%
Moderate high level	23.4%	52.2%	72.6%
High level	68.3%	27.0%	11.6%

The final questionnaire was answered by 75% of students; all of them had previously completed the initial questionnaire. The decrease in the number of students completing the survey is probably due to the fact that, at the end of the school-year, teachers had more difficulties and less time to verify that students filled it. However, Cronbach Alpha is very high (0.90), showing a high reliability of the items. In order to exclude the hypothesis that students who did not answer to the final questionnaire were concentrated in the lowest levels of initial engagement, a Chi-squared test was run to verify the incidence of having or not having answered to the final questionnaire on the distributions of the initial levels of emotional, cognitive and behavioral engagement. None of the tests gave significant results ($p=0.25$ for emotional engagement; $p=0.33$ for cognitive engagement; $p=0.66$ for behavioral engagement), meaning that answerers and non-answerers were equally distributed in terms of initial engagement.

As a preliminary analysis, variance analysis (ANOVA) was conducted over the students' answers on the single final questionnaire items of the two subscales, considering as independent variables the corresponding level of initial engagement, emotional or cognitive. For almost all the items, the initial level of engagement did not explain students' answers ($p>0.1$); for some items the trend was even decreasing, meaning that students with low levels of engagement showed a higher interest for this kind of activities than their classmates; only items QF2 and QF6 registered a significative, though weak, dependence on the initial emotional engagement level. Table IV reports some examples of students' answers to the items of the cognitive subscales, analyzed for levels of initial engagement.

TABLE IV. EXAMPLES OF STUDENTS' ANSWERS TO THE FINAL QUESTIONNAIRE FOR LEVEL OF COGNITIVE ENGAGEMENT

Initial cognitive engagement level	**Means of students' answers**		
	QF14	***QF10***	***QF13***
Low level	3.66	4.07	3.59
Moderate high level	3.53	3.96	3.53
High level	3.81	4.30	3.66
p-value	0.31	0.16	0.75

These results are promising for our research question; however, as one can reasonably suppose, students in the highest initial levels of engagement tended to give higher answers than students from lowest levels: deeper analyses are needed in order to show the impact of the adopted methodologies on initially demotivated students.

Factor analysis, repeated on the final questionnaire, left the original schema unchanged: thus, two standardized variables, one expressing the cognitive engagement and the other expressing emotional engagement, were created as output of the factor analysis; they embed the students' answers to the items considered in Table II. Moreover, ANOVA analysis was conducted over these variables, considering the corresponding initial engagement levels (EE_cat and CE_cat) as independent variables. Results were once again not significant, showing initially highly engaged students a little more engaged in online activities than the others, making it difficult to draw further conclusions.

In order to investigate whether any effect occurred on changes in the factors of student engagement, the difference between the level of emotional engagement with online activities observed with the final questionnaire and the initial level of emotional engagement was computed; the same was done for cognitive engagement. The variable expressing the difference in emotional engagement (EE_diff) has mean -0.062 and standard deviation 1.276; the variable expressing the difference in cognitive engagement (CE_diff) has mean -0.022 and standard deviation 1.329.

Through ANOVA, the dependence of EE_diff from the initial categorical level of emotional engagement (EE_cat) was tested. Results are reported in Table V: students with initial low levels of emotional engagement improved their level by 1.580, which is more than one standard deviation. The difference decreases as the initial engagement level increases. ANOVA test shows significant relations among the variables ($p<0.0001$); Eta test shows that this relation is moderate, explaining the 18% of the variance (Squared eta: 0.183, $p<0.0001$). The effect size, restricting the sample to students with initially low levels of engagement, is $d=1.15$, which is a noticeable value.

A similar analysis was conducted for cognitive engagement, by studying, through ANOVA, the dependence of CE_diff on the CE_cat. Results are reported in Table V: students with initial low levels of emotional engagement improved their level by 1.1810, which is similar to standard deviation. The difference decreases as the initial engagement level increases, reaching -1.076 for initially highly engaged students. ANOVA test shows significant relations among the variables ($p<0.0001$); Eta test shows that this relation is strong, explaining the 34% of the variance (Squared eta: 0.342, $p<0.0001$). The effect size, considering only students having low initial levels of engagement, is $d=1.08$, which is a very high value as well.

TABLE V. DIFFERENCES BETWEEN INITIAL AND FINAL LEVEL OF ENGAGEMENT, PER LEVEL OF INITIAL ENGAGEMENT

Initial level of emotional/cognitive engagement	***EE_diff***	***CE_diff***
Low level	1.5796	1.1810
Moderate high level	0.2747	0.1510
High level	-0.3393	-1.0764
p-value	<0.0001	<0.0001
Squared eta	0.183	0.342

The behavioral variables considered at the end of the didactic experience are: the number of logs registered in the platform, the number of submitted assignments on the platform and the rate of submission per assignment. Considering data from the informatic systems brings the advantage that they were collected for the whole 100% of students, so there are no missing data. Table VI shows means and standard deviations of the three variables.

TABLE VI. DATA FROM THE PLATFORM USAGE

Variables	***Mean***	***S.D.***
Number of logs	96.51	72.48
Number of assignment submissions	18.65	17.15
Rate of submission per assignment	1.66	0.87

From the literature we already know that logs are related to behavioral engagement, but they can be influenced by other factors, so they are not reliable indicators [19]. As a matter of fact, in our analysis 28% of variances of the number of log and 26% of variances of the number of submissions is explained by the class teacher: probably the way teachers asked students to do the online activities and the way they checked the homework impacted on student work. These variables turn out to be weakly associated with the initial level of behavioral engagement, as shown in Table VII: students with a low level of behavioral engagement tended to work less on the platform than their classmates. For the number of submissions, the relation is statistically significative; for the number of logs, however, there is not statistical evidence.

The situation changes when considering the average rate of resubmission per assignments. Recalling that the assignments have unlimited attempts, that numbers and situations change at every attempt and that mistakes are explained through interactive feedback, when students try questions again it means that they are eager to autonomously solve the problem, that they understood the solution and want to challenge themselves once again: thus, the task managed to engage students. This variable seems not to be related to the initial behavioral engagement level, as shown in Table VII (p=0.21). Even students with initially low levels of behavioral engagement could be engaged by activities with automatic formative assessment.

TABLE VII. AVERAGE DATA FROM THE PLATORM, PER LEVEL OF INITIAL BEHAVIORAL ENGAGEMENT

Initial level of behavioral engagement	***Number of logs***	***Number of submissions***	***Rate of submissions per assignment***
Low level	78.52	14.52	1.75
Moderate high level	97.33	18.45	1.60
High level	116.06	25.56	1.89
p-value	0.079	0.020	0.210

Lastly, we focused on the socio-economic status of the students, with the purpose of verifying that the online activities experimented were useful also to students with challenging backgrounds. Through ANOVA tests, we noticed that the two groups registered similar values in the difference between final and initial emotional engagement (p=0.273); from a cognitive point of view, engagement level grew more for students from a lower social class than those from a higher one (p=0.041); the same trend was registered in the rate of submission per assignment (p=0.027). Results are displayed in Table VIII. These results are extremely important since the sociocultural origin is a strong predictor of scholastic success [18]. Engaging students from low socio-economic status is challenging, but important to prevent drop-outs.

TABLE VIII. IMPACT ON ENGAGEMENT ON STUDENTS OF DIFFERENT SOCIO-ECONOMIC STATUS

Socio-economic status	***EE_diff***	***CE_diff***	***Rate of submissions per assignment***
Low	-0.204	0.252	1.80
Medium-high	0.024	-0.188	1.54
p-value	0.273	0.041	0.027

VI. DISCUSSION AND CONCLUSION

The data analysis showed that the online activities, designed accordingly to the model of automatic formative assessment with interactive feedback developed by the research group, successfully contributed to the engagement of students that initially showed little involvement in school. The theoretical framework on engagement helped distinguish the components and define variables to measure student engagement. We showed that students who, at the beginning of the school year, were little emotionally engaged with Mathematics, that is, they had little interest toward things learned and felt little enjoyment when learning Mathematics, could be engaged with this kind of online activities. We found out that students who are initially highly engaged with Mathematics remained engaged with this kind of activities, however the most important effects are perceived on initially little engaged students, whose engagement could increase.

The online activities managed to catch student attention thanks to the use of the computer, that is still an unusual practice in the majority of 8^{th} grade classes in Italy, and thanks to the real-world settings, which help students associate a meaning to abstract concepts. The possibility to individuate, self-correct and understand mistakes offered by the automatic formative assessment is not possible with a traditional paper textbook: students acknowledge that this kind of work help them improve and value it. Moreover, the interactive feedback opens a dialogue between students and the system and encourages them to understand solving processes. There is a big difference between reading an example of correct resolution from a book or a file, or hearing it from the teacher at the blackboard, and following an interactive path where you are asked to insert answers to sub-tasks at each step. The latter is undoubtedly more engaging, under a cognitive perspective. Thus, even those students who, at the beginning of the school year, did not show much behavioral engagement towards Mathematics, that is, they were used to carry out little mathematical activity outside school and not to persevere in mathematical tasks, using the automatic assessment changed their attitude and made more attempts to the assignments. Seeing their scores increasing, their emotional engagement increased as well, and so did their cognitive engagement and their learning results, starting that positive loop that traditional instruction often fails to activate [1]. The impact of the activities on students with challenging backgrounds is of considerable importance, too. It is shown that school disengagement is related to disaffection, bullying, early school leaving and criminality. Increasing students' engagement in such environments is an outstanding goal [15].

The activities monitored in this project were not occasional practices, but they were regularly used over the school-year. Some teachers decided to exclusively use the online platform for assigning homework, thus abandoning the textbook. The final questionnaire was administered after 6 months of regular online activities: we can suppose that the effects on engagement acquired stability and could influence student beliefs towards Mathematics. If a similar methodology could become part of the everyday teacher practice as it was for the classes included in the experimentation, there would be decisive enhancements in the culture of Mathematics. It is fundamental to connect schools and universities with similar projects, that offer essential materials and data for advances in the research, but also valuable learning experiences for students. Many teachers who participated to the project enrolled to a teacher training course about these methodologies the following year, with the purpose of continuing to use these kinds of activities and becoming autonomous in the preparation of learning materials [40].

The University of Turin is experimenting similar educational models using the same technological asset for learning other disciplines, such as Science, Latin and Foreign Languages. Interdisciplinary research collaborations are essential to develop innovative materials for learning and new insights for the research.

REFERENCES

[1] C. Ng, B. Bartlett, and S. N. Elliott, Empowering engagement: creating learning opportunities for students from challenging backgrounds. New York, NY: Springer Science+Business Media, 2018.

[2] J.J. Appleton, S.L. Christenson, D. Kim, and A.L. Reschly, “Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument,” in Journal of School Psychology, vol. 44, no. 5, pp. 427–445, 2006.

[3] Y. Xiong, H. Li, M.L. Kornhaber, H.K. Suen, B. Pursel, and D.D. Goins, “Examining the Relations among Student Motivation, Engagement, and Retention in a MOOC: A Structural Equation Modeling Approach,” in Global Education Review, vol. 2, no. 3, pp. 23–33, 2015

[4] K. Jordan, “Initial trends in enrolment and completion of massive open online courses,” The International Review of Research in Open and Distributed Learning, vol. 15, no. 1, 2014.

[5] J.A.C. Hattie, Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement. Routledge, 2009.

[6] E.A. Skinner and J.R. Pitzer, “Developmental Dynamics of Student Engagement, Coping, and Everyday Resilience,” in Handbook of Research on Student Engagement, S.L. Christenson, A.L. Reschly, and C. Wylie, Eds. Boston, MA: Springer US, 2012, pp. 21–44.

[7] M.T.H. Chi and R. Wylie, “The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes,” in Educational Psychologist, vol. 49, no. 4, pp. 219–243, 2014.

[8] Y.F. Yang, “Engaging students in an online situated language learning environment,” in Computer Assisted Language Learning, vol. 24, no. 2, pp. 181–198, 2011.

[9] H.M. Marks, “Student Engagement in Instructional Activity: Patterns in the Elementary, Middle, and High School Years,” in American Educational Research Journal, vol. 37, no. 1, pp. 153–184, 2000.

[10] R. Pierce, K. Stacey, and A. Barkatsas, “A scale for monitoring students’ attitudes to learning mathematics with technology,” in Computers & Education, vol. 48, no. 2, pp. 285–300, 2007.

[11] J.A. Fredricks and W. McColskey, “The Measurement of Student Engagement: A Comparative Analysis of Various Methods and Student Self-report Instruments,” in Handbook of Research on Student Engagement, S.L. Christenson, A.L. Reschly, and C. Wylie, Eds. Boston, MA: Springer US, 2012, pp. 763–782.

[12] J.A. Fredricks, P.C. Blumenfeld, and A.H. Paris, “School Engagement: Potential of the Concept, State of the Evidence,” in Review of Educational Research, vol. 74, no. 1, pp. 59–109, 2004.

[13] V. Dagley, “Making the invisible visible: a methodological and a substantive issue,” in Educational Action Research, vol. 12, no. 4, pp. 613–630, 2004.

[14] J.J. Appleton, S.L. Christenson, and M.J. Furlong, “Student engagement with school: Critical conceptual and methodological issues of the construct,” in Psychology in the Schools, vol. 45, no. 5, pp. 369–386, 2008.

[15] H. Patrick, A. M. Ryan, and A. Kaplan, “Early adolescents’ perceptions of the classroom social environment, motivational beliefs, and engagement.,” in Journal of Educational Psychology, vol. 99, no. 1, pp. 83–98, 2007.

[16] T.A. Kindermann, “Effects of Naturally Existing Peer Groups on Changes in Academic Engagement in a Cohort of Sixth Graders,” in Child Development, vol. 78, no. 4, pp. 1186–1203, 2007.

[17] OECD, Low-performing students: why they fall behind and how to help them succeed. Paris: OECD Publishing, 2016.

[18] OECD, PISA 2012 results: Ready to learn, vol. 3. Paris: OECD, 2013.

[19] C.R. Henrie, L.R. Halverson, and C.R. Graham, “Measuring student engagement in technology-mediated learning: A review,” in Computers & Education, vol. 90, pp. 36–53, 2015.

[20] F. Gossen, D. Kuhn, T. Margaria, and A.L. Lamprecht, “Computational Thinking: Learning by Doing with the Cinco Adventure Game Tool,” in Proceedings of 2018 IEEE 42nd Annual Computer Software and Applications Conference, 2018, pp. 990–999.

[21] M. Prince, “Does Active Learning Work? A Review of the Research,” in Journal of Engineering Education, vol. 93, no. 3, pp. 223–231, 2004.

[22] D. Nicol and C. Milligan, “Rethinking technology-supported assessment practices in relation to the seven principles of good feedback practice,” in Innovative Assessment in Higher Education, C. Bryan. and K. Clegg., Eds, Taylor and Francis Group, 2006, pp. 1–14.

[23] A. Barana, M. Fioravera, M. Marchisio, and S. Rabellino, “Adaptive Teaching Supported by ICTs to Reduce the School Failure in the Project ‘Scuola Dei Compiti,’” in Proceedings of 2017 IEEE 41st Annual Computer Software and Applications Conference, 2017, pp. 432–437.

[24] A. Barana, A. Bogino, M. Fioravera, M. Marchisio, and S. Rabellino, “Open Platform of self-paced MOOCs for the continual improvement of Academic Guidance and Knowledge Strengthening in Tertiary Education,” in Journal of e-Learning and Knowledge Society, vol 13, no 3, pp. 109–119, 2017.

[25] A. Barana, A. Bogino, M. Fioravera, F. Floris, M. Marchisio, L. Operti and S. Rabellino, “Self-Paced Approach in Synergistic Model for Supporting and Testing Students,” in Proceedings of 2017 IEEE 41st Annual Computer Software and Applications Conference, 2017, pp. 407–412.

[26] A. Barana, M. Fioravera, and M. Marchisio, “Developing problem solving competences through the resolution of contextualized problems with an Advanced Computing Environment,” in Proceedings of the 3rd International Conference on Higher Education Advances, 2017, pp. 1015-1023.

[27] P. Black and D. Wiliam, “Developing the theory of formative assessment,” in Educational Assessment, Evaluation and Accountability, vol. 21, no. 1, pp. 5–31, 2009.

[28] A. Barana, S. Boffo, F. Gagliardi, R. Garuti, M. Marchisio, “Empowering Engagement in a Technology Enhanced Learning Environment”, in Proceedings of 4th conference on Smart Learning Ecosystems and Regional Development, in press.

[29] Moebius Assessment, available at https://www.digitaled.com/products/assessment/, last accessed 02-Jan-2019.

[30] A. Barana, M. Marchisio, and S. Rabellino, “Automated Assessment in Mathematics,” in Proceedings of 2015 IEEE 39th Annual Computer Software and Applications Conference, 2015, pp. 670–671.

[31] A. Barana, L. Di Caro, M. Fioravera, F. Floris, M. Marchisio, and S. Rabellino, “Sharing system of learning resources for adaptive strategies of scholastic remedial intervention,” in Proceedings of the 4th International Conference on Higher Education Advances, 2018, pp. 1495-1503.

[32] A. Barana and M. Marchisio, “Ten Good Reasons to Adopt an Automated Formative Assessment Model for Learning and Teaching Mathematics and Scientific Disciplines,” Procedia - Social and Behavioral Sciences, vol. 228, pp. 608–613, 2016.

[33] A. Barana, A. Conte, M. Fioravera, M. Marchisio, and S. Rabellino, “A Model of Formative Automatic Assessment and Interactive Feedback for STEM,” in Proceedings of 2018 IEEE 42nd Annual Computer Software and Applications Conference, 2018, pp. 1016–1025.

[34] A. Barana, M. Marchisio, and M. Sacchet, “Advantages of Using Automatic Formative Assessment for Learning Mathematics,” in Proceedings of 2018 TEA Conference, in press.

[35] A. Brancaccio, M. Marchisio, C. Palumbo, C. Pardini, A. Patrucco, and R. Zich, “Problem Posing and Solving: Strategic Italian key action to enhance teaching and learning Mathematics and Informatics in the high school,” in Proceedings of 2015 IEEE 39th Annual Computer Software and Applications Conference, 2015, pp. 845–850.

[36] A. Barana, M. Marchisio, e R. Miori, “MATE-BOOSTER: Design of an e-Learning Course to Boost Mathematical Competence”, in Proceedings of the 11th International Conference on Computer Supported Education (CSEDU 2019), 2019, vol. 1, pp. 280–291.

[37] OECD, PISA 2012 Technical Report. PISA, OECD Publishing, 2014.

[38] A. Barana, S. Boffo, F. Gagliardi, and M. Marchisio, “Problem Posing & Solving: a Digital Way to Learn Mathematics,” In press.

[39] J.A. Middleton and P.A. Spanias, “Motivation for Achievement in Mathematics: Findings, Generalizations, and Criticisms of the Research,” in Journal for Research in Mathematics Education, vol. 30, no. 1, p. 65-88, 1999.

[40] A. Barana, M. Fioravera, and M. Marchisio, “Teacher training: a model for introducing innovative digital methodologies for learning Mathematics,” in Proceedings of the 3rd International Conference on Higher Education Advances, 2017, pp. 608-616.

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