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COMPSAC 2020

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Teaching Mathematics in Scientific Bachelor Degrees Using a Blended Approach

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***Abstract*—Mathematics plays a pivotal role in most scientific disciplines, being them meant both inside and outside academic contexts, with applications in a large part of the jobs nowadays, and also in several situations of everyday life. If on one hand this is well recognized, as an expression like the *queen of the sciences* show, on the other hand it is usually not among the students' preferred subjects, both from the liking and the interest points of view. Furthermore, it is still partly believed that Mathematics cannot be properly learnt by everyone, since it is perceived that, for really mastering it, a specific personal attitude is necessary. Considering all this, we designed a course in which the approach is considerably devoted to applications, being it directed at students of a scientific bachelor program not mainly focused on Mathematics, and problem solving, that is the contextualization of problems in real life situations. For this purpose, we made use of technologies such as a Learning Management System integrated with an Advanced Computing Environment and an Automated Assessment System. It has been observed that the students, which are taking a program in Biotechnology, gained curiosity and interest in the subject, thus allowing in turn a better proficiency. Since interaction between learners is promoted, the students are made active users of the contents, and their learning paths can be adapted according to the personal needs. They have been able to improve also the self-consciousness of their skills. This has been an important achievement especially for (but not limiting to) their future as scientists, considering the role transversal skills play in science, such as teamwork or flexibility. Finally, the students were specifically able to recognize how the problem solving approach will help them in both university and job careers, and how the use of the software has been helpful too.**

Keywords — advanced computing environment; automated assessment system; blended learning; contextualized problems; learning management system; problem solving; teaching Mathematics; virtual learning environment.

I. Introduction

To design a Mathematics course for students of a scientific faculty, but not strictly devoted to the *hardest* STEM disciplines such as Mathematics, Physics or Computer Science, results to be a challenging task, since they are, and in particular Mathematics is, perceived as "obstacles" through their studies. Indeed, these students generally do not put them at the top of their liking scale, and these subjects are often tackled with a lack of interest, thus making appropriate for teachers to motivate well why they are important and to arouse interest around them. On the other hand, even among academics it is sometimes believed that these disciplines are not within reach for all learners, or alternatively that they are not subjects to be treated in depth within curricula which are not geared to any specific domain. This leads to consider the exam of Mathematics a little more than a "necessary step" through graduation, resulting in difficulties ranging from procrastination to repeated failure. In this paper we will devise a strategy helping the students of a scientific faculty which is focused on other disciplines, namely Molecular Biotechnology and Health Sciences, to gain a proper interest, and thus to efficiently develop competencies, mainly in Mathematics. These students are going to use the competencies relative to this subject, which include knowledge and abilities, in their applications, so the proper tools have to be known. A way to deal with the passage from theory to practice that proved to be successful in several other contexts is given by the problem solving approach, in which real life situations are modeled into mathematical problems. Indeed, Mathematics is the discipline *par excellence* developing problem solving competencies, since a large number of phenomena can be explained in terms of relations between quantities. On the other hand, digital competencies will be also of much use: if one wants to study a modeled real situation in the 21^{st} century, he/she is usually not called to doing computations by hand, for several reasons such as the time that can be saved by relying on computers. As a consequence, what has to be asked to the students can be focused on solving strategies, rather than verifying how much they are able to compute. The paper is structured as follows: Section II contains an overview about the state of the art around the main trends implied by our study. In Section III the research question is explicitly presented, while in Section IV an extensive description of the methodology is depicted. Section V is devoted to the presentation of the course we devise, while in Section VI the results with the relative discussion are provided. Finally, Section VII presents some final remarks.

II. State of the Art

A. Blended learning

One of the concepts which more recently arose in the panorama of modern learning techniques, with a remarkable interest from the researchers' and teachers' community, is the one called *blended learning*. One of the ways to define it is as an approach to education in which a student learns, at least partially, through the delivery of content and instruction via digital and online media, where the student is able to control some elements of his/her track, relative to time, place, path or

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pace; and at least partially in a supervised brick-and-mortar location away from home, provided that the modalities along each student's learning path within a course or subject are connected in an integrated learning experience [1, 2]. It is natural to observe that blended learning is highly context dependent, being the right equilibrium concerning personal and online contact between teachers and students not the same for every discipline. Therefore, the concept has been interpreted differently over time and disciplines. Terms as *hybrid learning*, *personalized learning*, *technology-enabled (enhanced) learning*, and *differentiated instruction*, have been used sometimes as synonyms of blended learning [3]. The existing research on blended learning is divided. Some authors point that blended learning concerns mindset and pedagogy rather than technology [4]. On the contrary, some other authors emphasize how blended learning concerns learning design and course delivery rather than learning itself [5], thus focusing more on the technological aspects of the technique. This is brought to the point that the term *blended teaching* is proposed as a replacement for blended learning, while institutional strategies are considered. However, regardless of any differences in interpretation or practice, the increased internet access of the latest years, paired with the systematic use of mobile platforms, is revealing pivotal in the obtainment of UNESCO's Sustainable Development Goals [6], both in developing and developed countries.

B. STEM Education

The disciplines involved in the STEM acronym, that are Science, Technology, Engineering and Mathematics, are not meant to be separate. Indeed, real-world applications make use of them in a cohesive way: a saying state that science without engineers is just philosophy, and engineering without scientists is just impossible. This is consistent, for example, with the design and the production of electronic devices of common use. Consequently, it is proper not to treat them as discrete subjects, but on the contrary to integrate them in an interdisciplinary approach. One of the challenges relative to the STEM education is to attract students toward these disciplines: several developed countries are reporting shortages of workers, although starting salaries for entry-level STEM jobs are on average considerably higher than the average relative to other jobs, and there are usually good possibilities to move up [7, 8]. STEM education has to begin in the first phases of schooling, since even from the primary school it is important to catch the interest of the children in these disciplines, in an age in which they are more prone to make new interests. On the other hand, it has to be taken into account that several students change the core subjects of their studies during time: it is not uncommon to see students following a track in Humanities at the high school, and then switching to a scientific program at the university. Since nonscientific tracks cannot usually give the same preparation in STEM compared to scientific tracks, it is important for them to give a solid training at the beginning of the university studies, in order to allow them to achieve their goals regardless of the gaps in their previous studies.

It is noteworthy that the University of Turin, in the latest years, carried on several research on new technologies in STEM teaching and learning [9, 10, 11]. A model of automatic formative assessment, which has been particularly tested with high schools, was also developed [10, 12].

C. Applications and Problem solving

One of the obstacles interposing between a student and his/her proficient learning of Mathematics is often a low interest for the subject. Indeed, it is frequent for them to think that Mathematics is not of much use in real life, thus considering it secondary with respect to other disciplines, regardless of the intrinsic difficulty which can be also higher for the latter ones. In order to overcome this obstacle, it is useful to help the students understand the real meaning of the topics studied, which can interest them in what lies behind a certain dynamics that can be described by means of mathematical tools. Starting points can be given to students, with the purpose of introducing themes which otherwise would not catch the right interest; the abstract concepts of Mathematics are linked with real situations, better if related to one or more disciplines constituting the core of their study program [13]. For example, biologists could discover what Biomathematics is and its importance in the study of the populations' evolution, and so on.

III. RESEARCH QUESTION

In light of what we established in the previous sections, the research question, motivating our study and its relative analysis, can be formulated as follows: *how can we help the students of a scientific program, which is however not mainly focused on Mathematics, in developing mathematical competencies*? In the rest of the paper we will give a possible answer, based on a certain methodology able to provide results which are discussed accordingly to the goal implied by the question.

IV. METHODOLOGY

We asked students to submit two questionnaires, an initial one in which students were asked to answer, among other questions, about their knowledge on Math technologies, and a final one in which they have to review the experience with the same methodology, along with more general questions about the subjects and the topics of the course, such as Mathematics and Statistics themselves, but also Computer Science competencies and problem solving approach. The analysis relative to how much the students took the activities proposed was developed by using data from both the Learning Management System (LMS) and the grades.

A. Advanced Computing Environment

An Advanced Computing Environment (ACE), is a software which allows to take advantage of both the user-friendliness of an interface, and the representation possibilities of scientific (e.g. mathematical) objects in a simple and functional manner. ACEs possess also graphical and interactive features, allowing to draw figures ranging from simple graphs of functions to animations, and to interact with them through proper options. This allows the students to improve their reasoning, thanks to the possibility to make numeric and symbolic computations, geometric views in two and three dimensions, actions on interactive components where the results can be analyzed by changing proper parameters in a handy way, thus developing computational thinking [14]. The student is thus helped in checking his/her learning process. For the development of our course, we made use of the ACE *Maple* [15], which allows the creation of interactive files.

B. Automated Assessment System

An Automated Assessment System (AAS) has several advantages: for example, it allows the possibility to do tests on a regular basis, by showing personalized feedbacks and monitoring the learning process through an extended span of time. In Mathematics, it could be useful to ask the students to explicitly write formulas, equations, sets, or other mathematical entities, which forms the solution or the intermediate steps of the solution of a given problem, rather than ask them to choose between a few choices in a multiple choice setting, which is not always appropriate [16, 17]. In order to allow an automatic system to evaluate correctly whether a mathematical entity is expressed correctly, an ACE could be used, being it able to recognize the set of the correct forms of a given expression (which are often more than one). The AAS *Möbius Assessment* [18] allows to take advantage of both an AAS and an ACE. By maintaining fixed the structure of the question, and modifying only the numerical values, they allow the students to learn from their errors. Hence, the error becomes part of the learning process [19]. An important feature of *Möbius Assessment* is the availability of the so-called *adaptive questions*, that are multipart questions in which a tailored path is proposed to the student depending on his/her answers. This methodology allows to introduce immediate feedbacks that are very useful in terms of formative assessment. Several studies [20] agree on the fact that a feedback is really effective if it can hastily inform on the correctness of the given answer, if it is not too long (otherwise, the students would tend not to read it), if it is specific for the considered answer, but, even more important, if it guides the students to the solution through an active process, which is the case here. They can give them even more self-consciousness on which they are really doing when studying, paired with the ability to learn more efficiently and to be personally involved in their improvement [21].

V. Mathematics for Biotechnologists

We now describe how the course is designed relatively to the methodology just presented. Around 180 undergraduate students, from the first year in Biotechnology are asked to follow a course named *Matematica e Biostatistica con Applicazioni Informatiche* (Mathematics and Biostatistics with Computer Science Applications). This is a course meant to give them Mathematical competencies but also digital and problem solving competences (soft skills) useful in their subsequent studies and during their career. In a regular classroom, 36 hours of Mathematics (mainly Linear Algebra and Calculus) and 16 hours of Biostatistics were provided. Additionally, we provide the students 12 hours in a room equipped with computers; during them, they were able to work with the ACE. Finally, 12 final hours were provided as exercises specifically targeted on the impending exam.

In the online course, apart from general info, students were encouraged to take part in various activities, often involving the ACE or the AAS. There is a section for every topic (vector calculus, matrix algebra, univariate calculus, integrals…), generally containing *Maple* worksheets with interactive components (presented in Section IV.A) and *Möbius Assessment* tests (depicted in Section IV.B).

The final exam was constituted by 12 questions, 8 relative to Mathematics, and 4 in reference with Biostatistics, in order to reflect roughly the proportion of the hours devoted to both sets of topics. Students have been able to obtain the maximum grade with a quota of correct answers around 85%, which has been considered adequate given the context. Students were also asked to write a term paper with the ACE, that was meant to be discussed after the exam with the AAS in an oral session, and which has been able to modify the grade obtained there. In this paper, a practical problem seen during the course, had to be considered and extended, in order to highlight what the student had been able to acquire both in terms of the subjects and the use of the ACE. The teachers were able to monitor, thanks to the data given by the platform [22], the activities undertaken by the students, the errors they committed, and to intervene whether some theoretical or practical concepts resulted to be particularly difficult for the students.

VI. Results and Discussion

We first analyze the results of the questionnaires, by comparing how certain opinions changed before taking the course versus after taking the course. In this and in the subsequent tables, evaluations were given in a scale from 1 (not at all) to 5 (very much).

TABLE I. SELF-EVALUATION ABOUT PROBLEM SOLVING APPROACH

Problem solving approach	**Before course**		**After course**		**Diff**
	Avg.	***S. D.***	***Avg.***	***S. D.***	
It helps learning the theory	3.60	0.94	3.66	1.14	0.06
It helps career in university	3.59	0.98	3.93	1.03	0.34
It helps career in job market	3.49	1.06	3.62	1.08	0.13

It is worthy to note that the best improvement occurred while asking about their university career: *if I study Mathematics also with problems posed in certain contexts, do I obtain a better outlook on my academic future*? The students gave credits also while asking about a better learning of the theoretical part of the course, and about obtaining a better outlook on their future in the job market, but with slightly lower results. The latter is probably motivated by their young age, and the perception of that market as “far” for them. Indeed, they will take at least two year and a half to obtain a bachelor’s degree, and many of them will continue studies as graduates, so their vision of the job market could be still a bit blurry. Table II shows how the AAS was better recognized by the students after having taken the course. In particular, the students did come to appreciate how it has been useful to solve exercises with random generated parameters, which in turn allowed them to simulate repeatedly tests that were constructed essentially similar, in terms of structure, to which it would have been the final exam. Also, the feature of being assessed immediately, not requiring a manual checking of the correctness of the answers, which moreover is not always available on exercises taken from textbooks, has been perceived as notably good.

TABLE II. SELF-EVALUATION ABOUT THE USE OF AN AAS

AAS	Before course		After course		Diff
	Avg.	*S. D.*	*Avg.*	*S. D.*	
It guarantees more equality	3.21	0.92	3.21	1.18	0.00
Random parameters are good	3.11	1.10	3.72	0.96	0.61
Immediate evaluation is good	4.05	0.78	4.24	0.95	0.19
Repeated simulation is good	3.95	0.71	4.21	0.82	0.26
Better understanding of errors	3.53	0.96	3.66	1.11	0.13

As a partial weakness, we would be able to mention that, although its evaluation is generally positive (i.e. above the *midpoint* 3) too, students were a bit more worried about equality. Indeed, we gave them also the chance to freely write some comments and observations on the overall perception of the course. In some of the posts they wrote, doubts about the possibility of being excessively penalized by wrong calculations emerged. The AAS is nevertheless capable to handle, from a symbolic point of view, several syntaxes, and from a numeric point of view, answers within a user-defined margin of error. Analogously, a question can be constructed such that answers relative to intermediate steps are required and give partial grades in case of errors elsewhere, even without making use of adaptive capabilities. It is likely that the students were used to write the extended solution of a problem in a setting in which their whole production during a test was read by the teacher. Thus, the idea of being evaluated only on answers to specific questions was somewhat "new" for them, which sparked some moderate mistrust among part of the class. Table III shows how their competencies in Mathematics and Statistics were perceived before and after having taken the course. We note a steady increase in the use of an ACE, which is also supported by the answers to another question, asked only at the end of the course: *in your opinion, how much the competencies acquired by using the ACE Maple will be useful in your future professional career*? That question resulted in an average of 2.97 and in a standard deviation of 0.94, confirming a perception which is very near the midpoint globally speaking, and moderately positive for some of the students. But, apart from the improvement, the score is still the lowest among the competencies. This is due to the difficulties in recovering from its very low counterpart belonging to the initial questionnaire, in which emerged how a consistent part of the students lacked a proper consideration of ACEs in the high school.

Let us analyze now how much the students took the activities proposed. Regarding the tests with the AAS, 13 different tests relative to single topics were made available (9 on Mathematics and 4 on Biostatistics), along with a general test on Biostatistics, and a test designed to simulate in the structure the final exam. Until the date of the first call, an average of 25.15 students, with a standard deviation of 7.61, took the specific tests. For the tests on Mathematics the average was 27.44 and the standard deviation 7.73, while for the tests on Biostatistics the two indices were respectively 20 and 4.62. The general tests saw 13 students taking the one on Biostatistics and 26 students taking the exam simulation. These results can be compared with the number of students who took the exam on the first call: 20.

TABLE III. SELF-EVALUATION ABOUT COMPETENCIES

Self-evaluation on:	Before course		After course		Diff
	Avg.	*S. D.*	*Avg.*	*S. D.*	
Theoretical knowledge	3.49	0.78	3.55	0.69	0.06
Computations	3.93	0.74	3.97	0.87	0.04
Graphics	3.53	0.91	3.62	0.90	0.09
Data analysis	3.18	0.94	3.48	0.87	0.30
Use of an ACE	1.76	0.97	2.62	0.68	0.86
Problem solving approach	2.99	1.02	3.28	0.96	0.29
Interdisciplinarity	3.09	0.93	3.45	0.91	0.36

It has to be noted that a relevant number of students decided to take the exam later for reasons not related to the structure of the course. Indeed, many of them want to retake the admission test in Medicine and Surgery, which will take place in September, in order to try studying as physicians rather than biotechnologists. Since in the Medicine and Surgery program there is not an exam in Mathematics concerning the topics constituting our course, they prefer to focus in the first place on other exams, such as Physics, which is present in that program, and can be generally transferred from one career to another if taken with success. But in our opinion this is not a limitation: on the contrary, in a certain sense, we ensure that the students considered for our survey are genuinely interested in a career as biotechnologists, thus validating our considerations about studying Mathematics while following another scientific program to obtain a degree in it (and not for different purposes in relation with other careers). We see that the number of students which took the simulation is higher than the amplitude of the group taking the exam, with 19 students taking both the simulation and the exam on the first call; in general, students taking the activities proposed were more eager to take the exam as soon as possible. On the other hand, some specific tests saw an even larger participation, for example the test on Vectors was taken by 43 students. This can be explained by inferring that a part of the cohort was interested in training but not in giving the exam as early as possible, by deciding this either at the beginning or during the course, possibly after having noted that more individual study was required for them. This is consistent with the personalized learning path capabilities of the blended learning paradigm.

TABLE IV. NUMBER OF STUDENTS TAKING AAS TESTS

Vectors	43	3D curves and surfaces	21
Linear Algebra	38	Differential equations	22
Univariate functions	27	Descriptive statistics	24
Univariate integrals	26	Probability	24
3D analytic geometry	23	Random variables	16
Bivariate functions	24	Inferential statistics	16
Bivariate integrals	23	**Specific average**	**25.15**
General biostatistics	**13**	**Exam simulation**	**26**

Table IV shows the number of students taking the various tests.

Concerning the worksheets with the ACE, we note an average number of students that opened at least once the resources which exceeds too the 20 students taking the exam on the first call. Table V shows how many users had access for every topic; for the sake of compactness, applications in Computer Science were regrouped as two topics, one relative to theory and one in reference with the solving of exercises and problems, both constituted by 4 worksheets, and of which average numbers are given:

TABLE V. NUMBER OF STUDENTS ACCESSING ACE RESOURCES

Vectors	65	Comp. Sci. Appl. (avg.th)	33.25
Linear Algebra	74	Comp. Sci. Appl. (avg.ex)	29.25
Univariate functions	95	**Weighted average**	**44**

An important feature relative to both cases is given by multiple access. Indeed, several students choose to open the resources more than once, which in the case of the AAS is consistent with the paradigm of the learning through errors which motivates the creation of questions with random parameters. Nevertheless, also if we consider the ACE, accessing multiple times to a certain resource means with all chance that the student wants to control its pace. For example, the first time it could simply viewed, while the second time a use of the interactive capabilities occurs; and this is again a trait of the blended learning scheme. Table VI show some examples of the ratio between the total number of accesses to a certain resource (by counting multiple accesses from the same student as different ones), and the number of students accessing it (whose data come from Tables IV and V), thus giving the average number of times a student opened it.

TABLE VI. AVERAGE NUMBER OF ACCESSES TO NOTABLE RESOURCES

AAS: Vectors	2.53	ACE: Vectors	1.94
AAS: Linear Algebra	2.68	ACE: Linear Algebra	1.53
AAS: Exam simulation	3.65	ACE: Univar. Functions	1.97

In the period October 2019 – February 2020 the number of weekly global accesses to the LMS by students was around 1,000. There were two maximums, one of more than 1,200 interventions in the last week of November, near the end of the classroom hours, and a second one of more than 2,500 readings in the week of January immediately preceding the first call.

We give now a brief overview of the term papers which students were asked to write with the ACE: they show how them profitably acquired both problem solving and digital competencies, as it was the goal of the given task. Fig. 1 shows an excerpt from one of these term papers: we see how a problem concerning a colony of bacteria, which can be solved in the first place with fixed values of the variables involved (this would be a "traditional" exercise, so we do not show it here), can be easily generalized to arbitrary values for them, thanks to the ACE capabilities. Indeed, a form allows to enter the data needed, such as initial number of bacteria, formula for food per capita, and two other coefficients, and to obtain as a result a plot of the number of bacteria versus time. Students were able to create these interactive files with some help from teachers and tutors but also with a considerably autonomous work, thus proving to have gained competencies in both of the aforementioned fields.

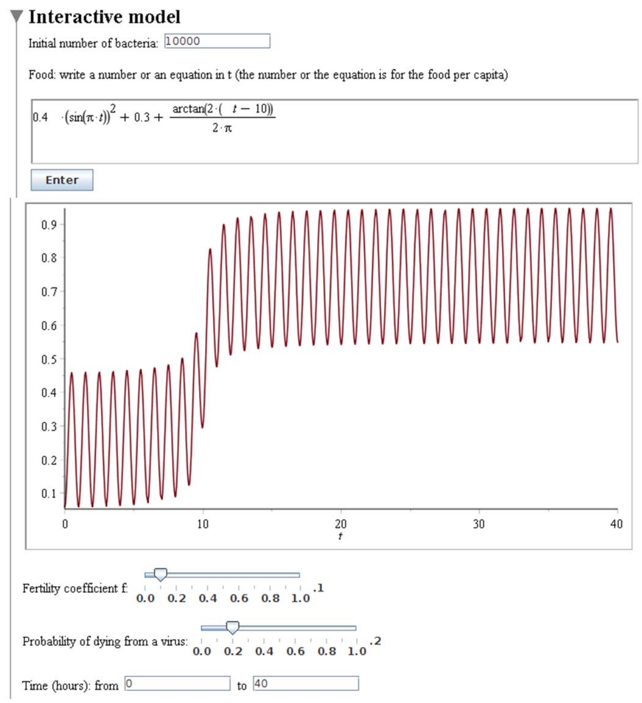

Fig. 1. An excerpt from a term paper redacted with the ACE, regarding a model about a colony of bacteria

Finally, let us analyze the grades: by considering the ones relative to the exam with the AAS, before the modifications due to the paper term with the ACE (which were slight, although submitting that paper was mandatory for taking the exam), in reference with the first call, every student has been sufficient, being the lowest grade (among the group of twenty) a 21 out of 30.

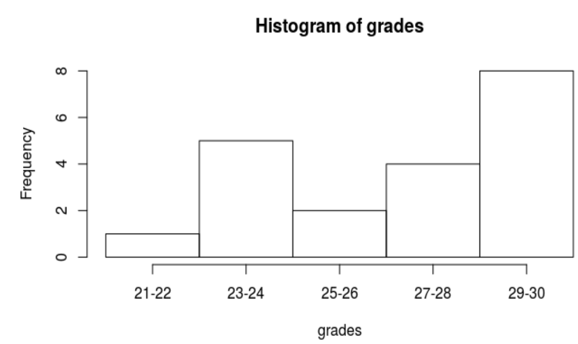

Fig. 2. Exam with the AAS: distribution of the grades.

This is a result which is surprising in a certain sense, since usually in programs of the area relative to biology and medicine, to which Biotechnology belongs, the percentage of failures in the Mathematics exam (or in the first one, provided that there are more exams on the subject) is considerably higher than 5%, thus giving one or more fail every 20 students. On the other hand, 5 out of 20 students took a grade of 30 out of 30, with 4 of them taking even a laude, which was awarded to students obtaining an exact evaluation higher than 30; again, we found that students taking the activities proposed took generally higher grades. Fig. 2 shows the distribution of the grades.

VII. Conclusions

We have seen how with the use in conjunction of a problem solving approach, a Learning Management System (LMS), an Advanced Computing Environment (ACE), and an Automated Assessment System (AAS), we were able to obtain promising results in the teaching of a course in Mathematics for non-mathematicians. Indeed, students from a program in Biotechnology, representing disciplines considerably different from the *hardest* STEM ones, were able to do better. This is to be meant in at least a double sense: on one hand, students achieved better grades, obtaining a collective result that was significantly above the expectations which were based on the outcome of the previous years, in which students had to take the exam "on paper", not in an interactive format, after following a traditionally structured course. On the other hand, they improved their consideration of the problem solving approach, and more in general of studying Mathematics, recognizing the importance of the aid given by the ACE and the AAS. In some sense, this is even more important, since the students were able to valorize their general capabilities on the subject, which can be useful both for possible subsequent mathematical courses, and for future jobs in a scientific context. In particular, these results gave a positive answer in terms of whether the use of blended learning during the course by teachers and tutors had been effective for students: indeed, they were able to improve their self-evaluation, their competencies, and finally their grades. As future work, a challenging idea could be to extend what we have done here for programs and departments even more distant from Mathematics than Biotechnology. Indeed, some competencies given by the mathematical sciences belong to the area of the transversal skills, that can be useful throughout academic contexts and outside them, and in particular for students taking a linguistic program or in Humanities. On the other hand, the use of the AAS has been adopted also in these disciplines, since parameters and adaptiveness can be fine-tuned in order to work also with words and phrases [23], and in Computer Science [24]. This means that, if a proper setting will be designed, students would be able to deal with the very same system they already know from their other disciplines, while studying or taking an exam in Mathematics.

References

[1] C. R. Graham, "Blended learning systems: Definition, current trends, and future directions", in The Handbook of blended learning: Global perspectives, local designs, C. J. Bonk and C. R. Graham (Eds.). San Francisco, CA: Jossey-Bass/Pfeiffer, 2006.

[2] C. Christiansen, M. Horn and H. Staker, "Is K-12 blended learning disruptive? An introduction to the theory of hybrids". Clayton Christensen's Institute for disruptive innovation, 2013.

[3] Commonwealth of Learning, "Open and distance learning: Key terms and definitions", 2015.

[4] A. Powell, B. Rabbitt and K. Kennedy (Eds), "iNACOL blended learning teacher competency framework: iNACOL in partnership with The Learning Accelerator". iNACOL, The International Association for K-12 Online Learning, 2014.

[5] J. Daniel, "Making sense of blended learning: Treasuring an older tradition or finding a better future?". Contact North | Contact Nord Research Associate (web log post February 24), 2016.

[6] E. Ossiannilsson, "Blended Learning State of the Nation". International Council for Open and Distance Education (ICDE), 2017.

[7] E. J. Hom, "What is STEM Education?". Live Science (web log post February 11), 2014.

[8] L. Thibaut, S. Ceuppens, H. De Loof, J. De Meester, L. Goovaerts, et al., "Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education", European Journal of STEM Education, vol. 3(1), num. 02, 2018.

[9] A. Barana, M. Marchisio and S. Rabellino, "Empowering engagement through automatic formative assessment", in Proceedings of IEEE 43rd Annual Computer Software and Applications Conference (COMPSAC2019), IEEE, pp. 216-225, 2019.

[10] A. Barana, M. Marchisio and 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 (CSEDU2019), pp. 280-291, 2019.

[11] A. Barana, M. Marchisio and M. Sacchet, "Advantages of using automatic formative assessment for learning Mathematics", Communications in Computer and Information Science, 1014, pp. 180-198, 2019.

[12] A. Barana, A. Conte, M. Fioravera, M. Marchisio and S. Rabellino, "Model of automatic assessment and interactive feedback", in Proceedings of IEEE 42nd COMPSAC Conference, IEEE, pp. 1016-1025, 2018.

[13] A. Brancaccio, M. Marchisio, C. Meneghini and C. Pardini, "More SMART Mathematics and Science for teaching and learning", Mondo Digitale, 14(58), pp. 1-8, 2015.

[14] A. Barana, A. Conte, C. Fissore, F. Floris, M. Marchisio and M. Sacchet, "The creation of animated graphs to develop computational thinking and support STEM education", in Gerhard J., Kotsireas I. (Eds.), Maple Conference 2019: Maple in Mathematics Education and Research, pp. 189-204. Cham, Springer, 2020.

[15] Maplesoft, https://www.maplesoft.com

[16] A. Barana, M. Marchisio and S. Rabellino, "Automated Assessment in Mathematics", in Proceedings of IEEE 39th COMPSAC Conference, IEEE, pp. 670-671, 2015.

[17] G. P. Wiggins, "Assessing student performance. Exploring the purposes and limits of testing". San Francisco, CA: Jossey-Bass Publishers, 1993.

[18] Möbius Assessment, DigitalEd, https://www.digitaled.com

[19] M. Scriven, "The Methodology of Evaluation", in Gagné R. M., Tyler R. W., Scriven M. (Eds.), American Educational Research Association Monograph Series on Curriculum Evaluation, vol. 1: Perspectives of Curriculum Evaluation. Chicago, IL: Rand McNally, 1967.

[20] J. Hattie, "Visible Learning, A Synthesis of over 800 meta-analyses related to achievement", Abingdon-on-Thames: Routledge.

[21] 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 IEEE 41st COMPSAC Conference, IEEE, pp. 432-437, 2017.

[22] A. Barana, A. Conte, C. Fissore, M. Marchisio and S. Rabellino, "Learning analytics to improve formative assessment strategies", Journal of E-Learning and Knowledge Society, 15(3), pp. 75-88, 2019.

[23] C. Marello, M. Marchisio, M. Pulvirenti and C. Fissore, "Automatic assessment to enhance online dictionaries consultation skills", 16th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA2019), pp. 331-338, 2019.

[24] M. Marchisio, T. Margaria and M. Sacchet, "Automatic Formative Assessment in Computer Science: Guidance to Model-Driven Design", 44th COMPSAC Conference, IEEE, 2020, in press.

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