Establishing a New Paradigm for Teaching Mathematics at Engineering Schools

[1]Agustín de la Villa, [2]Alfonsa García, [2]Francisco García, [4]Alejandro Lois, [3]Ángel Martín del Rey, [4]Liliana Milevicich, [3]Gerardo Rodríguez

[1] Univ. Pontificia Comillas, [2]Universidad Politécnica, [3]Universidad de Salamanca (Spain), [4] Univ. Tecnológica Nacional (Argentina)

avilla@upcomillas.es, garcial@eui.upm.es, gmazario@eui.upm.es, alois@frgp.utn.edu.ar, delrey@usal.es, lmilevicich@frgp.utn.edu.ar, gerardo@usal.es

Abstract

This paper analyzes an ideal model of teaching, thinking after 5-10 years in Universities in the world. We propose the collaborative work for a fruitful learning. According with that, we expose some of our previous projects in this area and some ideas for the "global education", focused on the teaching and learning of mathematics to engineering students.

Furthermore we explain some of our initiatives for implementing the "Bologna process". Aspects related to the learning and assessments will be analyzed. The establishment of the new teaching paradigm has to change the learning process and we will suggest some possible initiatives for adapting the learning to the new model.

The paper ends by collecting some conclusions.

1. Introduction: Reality or fiction

1.1 We have a dream

In September 2020 the Linear Algebra Professor at a European university starts the introduction to his subject through a videoconference involving students from different nationalities across Europe, America and Asia.

The design presented includes different multilingual teaching materials: interactive e-books and on-line learning activities with proposed problems and practical tasks using an appropriate CAS (Computer Algebra System). An almost personalized tutorial system is developed, linked to the Mathematics Centre of the university, where students are able to receive tutorials about the CAS to be used and can tackle the problems arising in their studies. Finally, assessment is achieved by the application of personalized questionnaires on-line, with access to learning resources for students. The groups of instructors responsible help students to solve any academic problem.

1.2 Education is a shared task

If we now look to the summer of 2013, that situation might seem like a dream. The possibility described above needs academic agreements forged between the various political authorities, who must recognize the validity of the studies followed. Despite this, the technology is available and it is now possible to design a subject under these conditions. Nevertheless, a change in the global paradigm is necessary because the task of educating and training our students is a shared task. We need to train stable, open multinational teaching teams so that the elaboration of multilingual teaching materials and the development of a new assessment standard that uses existing education technology will be easy to implement.

We are certainly not starting out from zero. In recent years several of the authors of this contribution have participated in different projects in the European setting with this aim, such as dMath [1], EVLM [2] and WEBMLS [3] among others. Mathematics Centers are already a reality at different European universities. On line assessment supported by CAS, with sophisticated tailored feedback, partial credit and randomization is now possible (see [4]), and the possibility of deploying personalized questionnaires, to math students is available thanks to the STACK [5] technology and currently ongoing multinational projects, such as WEPS [6]. European and Latin-American integration is also under way. Our dream of September 2020 is beginning to see the light of day.

2. Towards the global education: Some initiatives

The sphere of university education has not been unaware of the normative changes in an increasingly globalized world. The need to use education technology efficiently, and in recent years the observation that the problems to be solved during our students' training phase go beyond the local remit have enabled the creation of supranational frameworks of educational cooperation.

Since the Bologna Accord [7] series of successive ministerial meetings have gradually consolidated the EHEA [8], aimed to harmonize the different national university educational systems. All the measures adopted (in what is commonly known as the "Bologna process") along the path of the development of EHEA should facilitate integration of the various university studies. This route has changed the teaching process since it requires substantial changes in methodology, in attending to our students' needs and in all assessment processes. The route covered so far has had to contend with the inertia of all those involved in the process. For all those involved, the change demanded requires us to abandon our traditional and comfortable structures and to become engaged in furthering current advances in a more permanent and pro-active way.

Less well known, at least from the European perspective, is the process begun in Latin-America for the creation of a supranational space of cooperation in higher education.

With the creation of the EHEA, educational researchers began to speak in both sides of the Atlantic on whether or not a Ibero Higher Education (EIES) allowing further close cooperation between the different university systems. The analysis of documents, agreements, regulations and other elements provide evidence in that sense. The VXI Conference, which took place in Montevideo, Uruguay, in 2006, was where the foundations of the so-called Latin American Knowledge Space (EIC) were laid, as an area in which to promote and strengthen regional integration and foster interaction and cooperation for the generation, dissemination and transfer of knowledge on the basis of complementarity and mutual benefit, and also the results on improving the quality and relevance of Higher Education, innovation and scientific research to promote the sustainable development of the region.

In the last three years it was made a remarkable effort. The Conference held in Buenos Aires in 2012 made it a priority to consolidate networks and spaces of knowledge at regional and international levels, to promote the cooperation between universities and academic mobility and to boost transformations aimed to reaffirm the mission of universities in new contexts, offering more choices for students and enabling more appropriate responses to social demands.

Similarly, in 2011 in Asunción, Paraguay and 2012 in Salamanca, Spain, it was agreed to ask the Organization of Ibero-American States to take the necessary steps to establish alliances with extra-regional countries, organizations and companies, and obtain resources from public, private and civil society organizations, as well as join efforts of international cooperation for the enforcement of the 2021 Education Goals. More information can be found in [9]. The bases for global educational cooperation are already laid down.

3. A new paradigm

3.1. Our state of art

The first consequence of setting up a global frame is the need to establish a new teaching paradigm. In our opinion, validated by our work and our participation in numerous innovative education projects, both domestic and international, there are three main needs that can find an answer in the setting up of a stable, open educational networks aimed at allowing the incorporation of new elements: the need to redesign mathematics subjects, elaborate quality teaching material and change currently existing but obsolete assessment systems.

In recent years, through different types of teaching innovation experiments and participation in the above European projects we have built a stable, open teaching team to adapt the different math subjects in our University Schools of Engineering to the new teaching scenario. We encapsulate the evolution of our thinking in a few references. References [10] y [11] address the possibilities of the use of CAS in math subjects, specifically Calculus in Several Variables and Differential Equations. Also, the use of CAS may involve an innovation in teaching, as seen from references [12] and [13]. We also encourage the students for the construction of toolboxes [14]. The next step is the adaptation of the Bologna Accord specifications in teaching with CAS [15], [16] and [17]. For a globalized process of

teaching it is crucial to choose a suitable CAS. One important argument in this is the ease of access and in general, it is preferable to use open-code, freely distributed software. Experience with different types of CAS and the comparative study described in [18] support this priority. Now may be the time to consider the new devices than can be called hand-held technology. Drijvers and Trouche [19] suggest that we should be aware that hand-held technology is no longer an isolated artifact but integrated in and articulated within a network of resources, particularly on-line resources.

Our team has already begun to construct new teaching materials, elaborating university manuals that cover the different basic math contents: Linear Algebra, Single Variable Calculus, Calculus of Several Variables and Ordinary Differential Equations. All the texts have a similar structure and can be used in many very different ways both by professors and by the students of the various courses. This flexible use is further supported by a CD with material to complement the text. This CD includes different exercises using different CAS: Derive, Maxima, Maple, Mathematica, etc. The use of CAS is not limited to computer facilities with the usual laboratory sessions to learn how to manage the software; instead, daily teaching practice uses the CAS as a routine teaching tool.

Although our universities require class attendance, currently our teaching can be said to be imparted within the context of b-learning. Thus, using a platform for the management of educational resources such as MOODLE students can engage in certain learning activities on-line. Collaboration in the elaboration of these new materials is beginning to become transnational. We now have a course on single variable calculus on the WEPS portal, with material elaborated in conjunction with instructors from different countries. This course is the main result of the recently finished European WEBMLS project.

Naturally, the assessment system has been modified. Our students are invited to participate in small tutored projects (individually or as groups) related to the specific area of engineering they are studying, see [20]. They complete some individualized questionnaires on line. The elaboration of Items Banks using the STACK system is part of the transnational tasks we are currently implementing with the WEPS virtual platform. We have also implemented some experiences for evaluating competences [21]. As well as these assessment mechanisms, we still run traditional exams (demanding the physical presence of the students) addressing problem solving. With this mixed assessment system we have managed to increase, in some cases spectacularly so, the percentages of students passing their math courses.

The student academic attendance system is mixed. As well as the usual tutorials held face-to-face the students can obtain help on-line through the MOODLE platform, which –as is known- also allows chats among the students for them to exchange their experiences.

3.2. The next milestones towards the future

We have seen the bases on which we shall be able to advance towards the near future. The authors of this contribution are currently engaged in the compilation of an interactive e-book, accessible from different electronic devices, that lays down the bases for the design of a more versatile subject, better adjusted to the training needs of engineers in their different specialties. We believe that it is necessary to offer instructors a tool that they can match to different educational needs. In this sense, electronic books can be a suitable basis for students, like the conductor of an orchestra who can interpret different scores. The presentation of this material in multilingual form, by taking advantage of global platforms such as WEPS, can allow its extended use by students at different universities.

To really advance along this path, some resistance must still be overcome. We refer in particular to resistance towards the use of educational technology in assessment processes. Many instructors defend assessment models based on traditional exams to evaluate the mathematical skills of their students. Some students also prefer a traditional assessment system, because the new models mean more autonomous work. Overcoming such resistance is therefore crucial for the immediate future.

Finally, the contacts set up through the above-mentioned transnational projects should culminate in the establishment of a stable network of instructors from different countries working on the elaboration of teaching and assessment materials that match the new teaching paradigm. The WEPS project could be a starting point in such an exciting task.

4. Conclusions

In light of the situation discussed above, the correct establishment of a global education space must necessarily involve enhancing the positive aspects of the new teaching paradigm, at the same time as attempting to reduce its possible negative effects. In this sense, the program of action proposed here can be expressed in the following conclusions:

-The need to strengthen international cooperation.
-The need of multinational teaching teams that will allow the establishment of a new paradigm in the teaching of mathematics in Engineering Schools based on the following key aspects:
-A new design of the traditional subjects in mathematics.
-The elaboration of quality learning materials that can be used by students from different universities and of different nationalities.
-A new formative assessment model, with individualized questionnaires that can allow efficient assessment of the competencies acquired by students.
-The design of a new integral support system for students.

References

[1] BRINGSLID, O. - RODRÍGUEZ, G., -VILLA, A. De la: "A European project for the restatement of engineering mathematics teaching" Proceedings of third international conference on the teaching of mathematics. Istambul (Turkey). 2006.
[2] http://portalevlm.usal.es/
[3] http://portalevlm.usal.es/
[4] SANGWING, C. "Assessing mathematics automatically using computer algebra and the Internet". Teaching Mathematics Applications, 2004, v.23 (1). Pages 1–14.
[5] http://www.stack.bham.ac.uk/
[6] https://myweps.com/moodle23/
[7] http://www.bologna-bergen2005.no/Docs/00-Main_doc/990719BOLOGNA_DECLARATION.PDF
[8] http://www.ehea.info/
[9] http://www.oei.es/cie.htm
[10] FRANCO, A.- FRANCO, GARCIA, A.- GARCIA, F.- GONZALEZ, F.J.- HOYA, S.-RODRIGUEZ, G.-VILLA, A: " Learning Calculus of Several Varibles with New Technologies". International Journal of Computer Algebra in Mathematics Education, 2000, v.7 (4). Pages 295-309.
[11] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G. -VILLA, A. de la: "A course of ODE with a CAS". Proceedings of Technology and its Integration in Mathematics Education. TIME-2004. Montreal (Canada)
[12] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G. -VILLA, A. de la: "Una propuesta de innovación educativa: Una enseñanza integrada del cálculo infinitesimal en las escuelas de ingeniería". Proceedings del XIII Congreso de Innovación Educativa en las Enseñanzas Técnicas. Maspalomas (Spain). September 2005.
[13] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G. -VILLA, A. de la: "Algunas estrategias en el uso de CAS en la enseñanza de las matemáticas en las Escuelas de ingeniería: Una perspectiva española". Actas del Octavo Simposio de educación matemática (EDUMAT). Buenos Aires (Argentina) June 2006.
[14] GARCÍA, A.- GARCIA, F.- RODRÍGUEZ, G.- VILLA, A. de la: "A Toolbox with DERIVE". Derive Newsletter number, 2009, v.76. Pages 5-13. ISSN 1990-7079.
[15] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G. - RODRÍGUEZ, V. -VILLA, A. de la: "One variable Calculus: A Spanish overview in accordance with EHEA". Proceedings 15th SEFI MWG Seminar and 8th Workshop GFC. Wismar. (Germany). June 2010
[16] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G.-VILLA, A. de la: "Learning and Assessing Competencies: New challenges for Mathematics in Engineering Degrees in Spain". Proceedings of 16th Seminar of Mathematics working group de SEFI. ISBN: 978-84-695-3960-6. Electronic version. Salamanca (Spain). June 2012
[17] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G.-VILLA, A. de la: "Changing Assessment Methods: New rules, new roles". Proceedings of Technology and its Integration in Mathematics Education TIME 2012. To appear in Journal Symbolic Computation.

[18] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G. - VILLA, A. de la: "Could it be possible to replace DERIVE with MAXIMA". The International Journal for Technology in Mathematics Education, 2011, v 18 (3). Pages 137-142. ISSN: 1744-2710.

[19] DRIJVER, P., TROUCHE, L. "Handheld technology for mathematics education: flashback into the future". ZDM Mathematics Education 42, 2010. Pages 667–681.

[20] GARCÍA, A.-GARCÍA, F.- RODRÍGUEZ, G.-VILLA, A. de la: "Small projects: A method for improving learning". Proceedings of 3rd International Research Symposium on Problem-Based Learning 2011. Coventry. United Kingdom. Pages 460-471. ISBN 978-87-7112-025-7.

[21] DÍAZ, A.-GARCÍA, A.-VILLA, A. de la: "An example of learning based on competences: Use of Maxima in Linear Algebra for Engineers". International Journal for Technology in Mathematics Education, 2011, v.18 (4). Pages 177-181. ISSN: 1744-2710.