WEB PLATFORM FOR THE INTEGRATION OF THEORETICAL CONTENT AND ITS APPLICATIONS IN ENGINEERING DEGREES: THE WOLFRAM DEMONSTRATIONS PROJECT

Luis Bayón, José M. Grau, José A. Otero, María M. Ruiz, Pedro M. Suárez

Polytechnic School of Engineering, Department of Mathematics, Gijón (SPAIN)
bayon@uniovi.es, grau@uniovi.es, jaurelio@uniovi.es, mruiz@uniovi.es, pedrosr@uniovi.es

Abstract

This paper presents a cross-curricular teaching innovation project which is to be developed during the academic year 2012-13 at the Polytechnic School of Engineering (EPI) in Gijon. The working group consists of 9 lecturers belonging to 5 departments. Work will be undertaken on the contents of 7 subjects forming part of the curricula of 5 degrees at the EPI. In this project we focus on the role of the Wolfram Demonstrations Project (WDP) in the teaching of diverse disciplines related to Engineering Degrees and show the advantages of using this application. The WDP resources, linked to specific contents of the course matter of each subject, will be presented to students via a website.

Keywords: Teaching innovation, online tools, innovation project, open-source resource.

1 INTRODUCTION

This paper presents a cross-curricular teaching innovation project which is to be developed during the academic year 2012-13 at the Polytechnic School of Engineering (Spanish acronym, EPI) in Gijon. The working group consists of **9 lecturers** belonging to **5 departments** (Physics, Physical and Analytical Chemistry, Construction and Manufacturing Engineering, Mathematics and Electrical Engineering, and Computer and Systems Electronics).

Work will be undertaken on the contents of **7 subjects** (Calculus, Advanced Mathematics, Electrical Technology, Transportation and Distribution of Electric Power, Theory of Structures and Industrial Buildings, Chemistry, Physical Chemistry III and Electromagnetism and Waves) forming part of the curricula of **5 degrees at the EPI**, Gijón (BEng in Industrial Technology, BEng in Electrical Engineering, BEng in Industrial Electronics and Automation, BEng in Mechanical Engineering and BEng in Chemical Engineering) and of the **BSc in Chemistry** at the Faculty of Chemistry:

In this project we focus on the role of the Wolfram Demonstrations Project (WDP) in the teaching of diverse disciplines related to Engineering Degrees and show the advantages of using this application. The WDP (http://demonstrations.wolfram.com/) is an open-source resource included in the resources that Mathematica makes available to students and teachers around the world. The WDP resources, linked to specific contents of the course matter of each subject, will be presented to students via a website. Lecturers as well as students will thus be able use them online: lecturers to impart classes and students to prepare the subject.

As a supplement to face-to-face teaching, this online teaching resource presents numerous advantages over the conventional lecture, reinforcing the role of the student as the central figure in the teaching-learning process. We shall see that, via the use of new technological tools and ICT, this interactive learning method constitutes a powerful tool for teaching innovation, which has become essential as a result of the implementation of the new curricula within the European Higher Education Area (EHEA).

The major goals of the project are to:

- Further develop management and coordination projects between lecturers as well as interdisciplinary projects.
- Develop and foster experiences that enable students to become autonomous in the process of virtual and life-long education.
- Incorporate technological tools and activities which integrate new resources.

- Create innovation projects related to online learning to supplement classroom teaching, in which coordination between lecturers must be paramount.

2 WOLFRAM DEMONSTRATIONS PROJECT

Mathematica [1] is a tool with endless applications and possibilities. The Wolfram website hosts an interactive collection of displays or demonstrations (called demos) of the Mathematica program called the Wolfram Demonstrations Project [2]. The Wolfram Demonstrations Project (WDP) is an open-source resource included in the resources that Mathematica makes available to students and teachers. This project uses dynamic computation to bring to life many concepts of science and technology and even art and finance, among others. The topics are organized by category, with interactive displays that are being constantly uploaded by users of Mathematica.

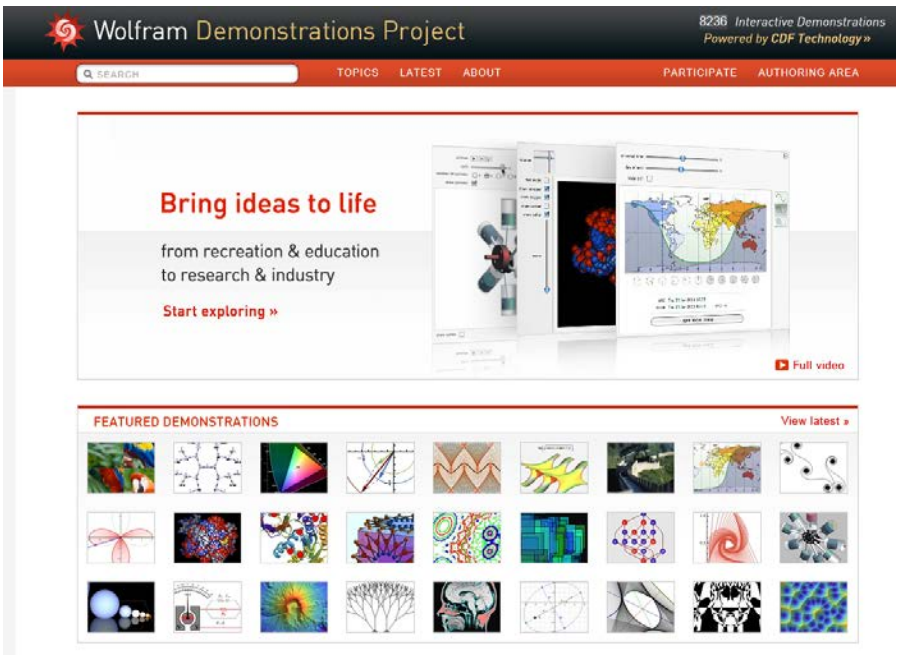


Figure 1. *Wolfram Demonstrations Project.*

This collection is being created day-by-day by thousands of users worldwide and contains applications involving topics from Algebra, Geometry, Astronomy, Economics, Engineering, etc., which help students learn. At the time of writing this paper (September 2012), the number is about 8300. All these demos, as well as their source code, can be downloaded for free and can be implemented on any computer running the Mathematica program or, even more comfortably, using the CDF Player freeware [3].

We define a demo as an interactive visualization of any concept. When interacting with the demo and moving a control, the user immediately sees the change in its output, thus facilitating understanding of the concept shown.

There is a search bar on the WDP home page [2]. You can also navigate using a very comprehensive menu organized by topic. In the specific case of the project at hand, the topics of interest are:

- ✓ **Mathematics**

  Algebra, Applied Mathematics, Calculus and Analysis, Discrete Mathematics, Experimental Mathematics, Geometry, Historical Mathematics, Number Theory, Pure Mathematics, Recreational Mathematics, and Statistics.

- ✓ **Computing**

  Algorithms, Computer Science, and Computer Systems.

- ✓ **Physics**

  Astronomy, Chemistry, Earth Sciences, History of Science, Materials Science, and Physics.

- ✓ **Systems, Models and Methods**

  Cellular Automata, Chaos Theory, Discrete Models, Experimental Methods, Fractals, Game Theory, Networks, Stochastic Processes, and Trees.

- ✓ **Engineering and Technology**

  Chemical Engineering, Civil Engineering, Control Theory, Electrical Engineering, Fluid Mechanics, Image Processing, Machines, Mechanical Engineering, Nanotechnology, Robotics, and Signal Processing.

After locating the desired demo, you can obtain a Flash preview if you so wish. This is very useful to check whether it meets the expectations you had for it. Demos can also be controlled by means of intuitive-to-use cursors.

If you like, you can download the actual demo with one click, without even having to register! There are two options here:

- Download the source code of Mathematica. The file will have the extension *.nb. Once the .nb file has been downloaded, you must have the Mathematica software installed on your computer to be able to open it. Mathematica version 6 (or higher) allows you to modify any demo by working on its source code to thus create new demos. Mathematica versions below 6 are inconsistent with the demos.
- Download the demo in the CDF format.

The Wolfram CDF Player freeware [3] allows you to run these demos on your computer as many times as they wish without having any knowledge of Mathematica. This constitutes a major advantage, especially in terms of its use by students at home.

The WDP website allows you to comment on each of the demos and to report bugs. There is also a direct link to make a new version of the demo. Naturally, comments are approved by the editors before being publicly displayed.

It should also be pointed out that the content of each demo is subject to a rigorous evaluation process, each contribution being reviewed by experts in the field. Once downloaded, the use of controls to handle the demo at will is simple, though far from limited. You can, for example: animate multiple controls, control the playback speed, choose an exact value for each control, save the settings chosen as favourites, print the demo and even control it with joysticks.

3 WEB PLATFORM

Next, we present the main point of our project. Our intention will not be restricted to simply giving a more or less extensive list of WDP demos. Our idea is to link each demo directly with its underlying theory. The effect is twofold: one the hand, visualizing the concept helps in understanding theory; and on the other, the demo is not a “magic box” in which the cursor is moved randomly, but rather, by comprehending its underlying basis, it is possible to exploit it to the full. Students can thus become autonomous in their learning process [4].

A website has been designed to implement the contents in a medium that allows easy access by lecturers and students alike (see Figure 2).

A template has been created that allows the user to easily find subject matter belonging to departments as diverse as Mathematics, Electrical Engineering, Physics, Chemistry, and Construction.

The scheme is as follows: The process commences by presenting the syllabus for each subject. A brief summary of the theoretical explanation needed to understand the topic is then presented. Finally, a link is provided to the WDP demo. The aim has been to link to demos that cover most of the syllabus of each subject, in a balanced way.

This will accordingly enhance online teaching. Students will also have access (for free and at home) to the same tools as the lecturer, thanks to which it will be much easier to become involved in following the course.

Finally, it should be noted that another goal is for students themselves to undertake some kind of assignment (individual or group) in each subject: the aim is to find new demos that can be

incorporated onto the website. The goal here is to activate student participation in the subject via the use of research assignments [5].

Figure 2. *Web Platform.*

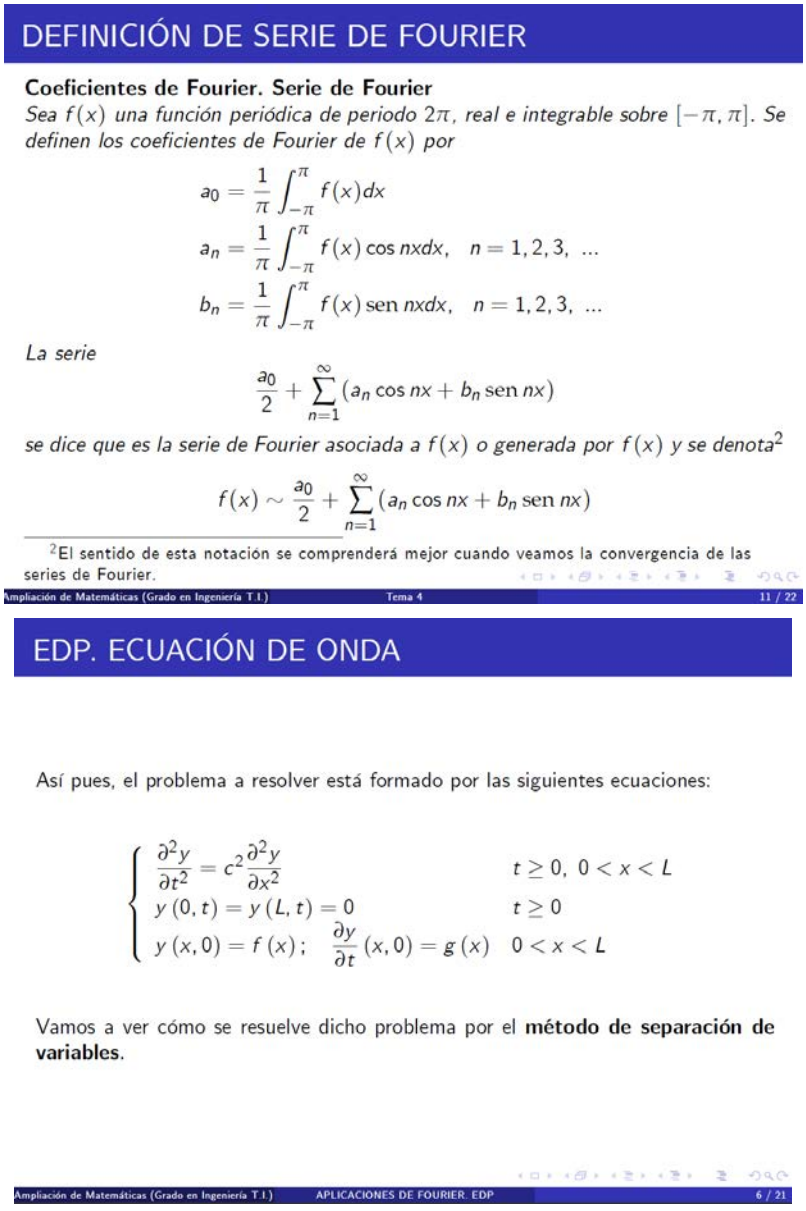
4 EXAMPLE

In this section, we present, as an example, one of the subjects that form part of the platform: Further Mathematics. The content matter of this subject consists of 5 topics. In each of these topics, the key points are presented with their corresponding theoretical content and associated WDP demos. Figure 3 shows an example of Topic 3, which corresponds to Fourier series.

Figure 3. *The Subject 'Advanced Mathematics' on the Web Platform.*

The PDFs (see Figure 4) provide a summary of the required theory for understanding the concept. It should be noted that this page does not include the complete notes of the subjects, only a brief description.

In the case at hand, Fourier series, the 22 slides of the first PDF suffice to describe the concept, state their properties, formalize the formulas for calculating the developments and analyse particular cases. The second PDF describes in 21 slides the method of separation of variables and its application to the wave equation as an example of solving Partial Differential Equations (PDEs).



DEFINICIÓN DE SERIE DE FOURIER

Coeficientes de Fourier. Serie de Fourier

Sea $f(x)$ una función periódica de periodo 2π, real e integrable sobre $[-\pi,\pi]$. Se definen los coeficientes de Fourier de $f(x)$ por

$$a_0 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)dx$$

$$a_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)\cos nxdx, \quad n = 1,2,3, \ \ldots$$

$$b_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)\,\mathrm{sen}\, nxdx, \quad n = 1,2,3, \ \ldots$$

La serie

$$\frac{a_0}{2} + \sum_{n=1}^{\infty}(a_n\cos nx + b_n\,\mathrm{sen}\, nx)$$

se dice que es la serie de Fourier asociada a $f(x)$ o generada por $f(x)$ y se denota[2]

$$f(x) \sim \frac{a_0}{2} + \sum_{n=1}^{\infty}(a_n\cos nx + b_n\,\mathrm{sen}\, nx)$$

[2]El sentido de esta notación se comprenderá mejor cuando veamos la convergencia de las series de Fourier.

Ampliación de Matemáticas (Grado en Ingeniería T.I.) Tema 4 11 / 22

EDP. ECUACIÓN DE ONDA

Así pues, el problema a resolver está formado por las siguientes ecuaciones:

$$\begin{cases} \dfrac{\partial^2 y}{\partial t^2} = c^2\dfrac{\partial^2 y}{\partial x^2} & t \geq 0,\ 0 < x < L \\ y(0,t) = y(L,t) = 0 & t \geq 0 \\ y(x,0) = f(x);\quad \dfrac{\partial y}{\partial t}(x,0) = g(x) & 0 < x < L \end{cases}$$

Vamos a ver cómo se resuelve dicho problema por el **método de separación de variables**.

Ampliación de Matemáticas (Grado en Ingeniería T.I.) APLICACIONES DE FOURIER. EDP 6 / 21

Figure 4. *PDF files.*

The WDP visualizations are presented next on the platform template (see Figure 5). In the first, a demo implements some of the most common functions: step, sawtooth, parabola, etc., and, through the use of controls, allows the user to visualize the effect of increasing the number of terms and the range of the interval in the approximation obtained.

The second demo provides a magnificent view of the solution obtained to the problem of the vibrating string. The student, who has previously obtained the solution of the PDE by the method of separation of variables, can now view the result in the corresponding animation.

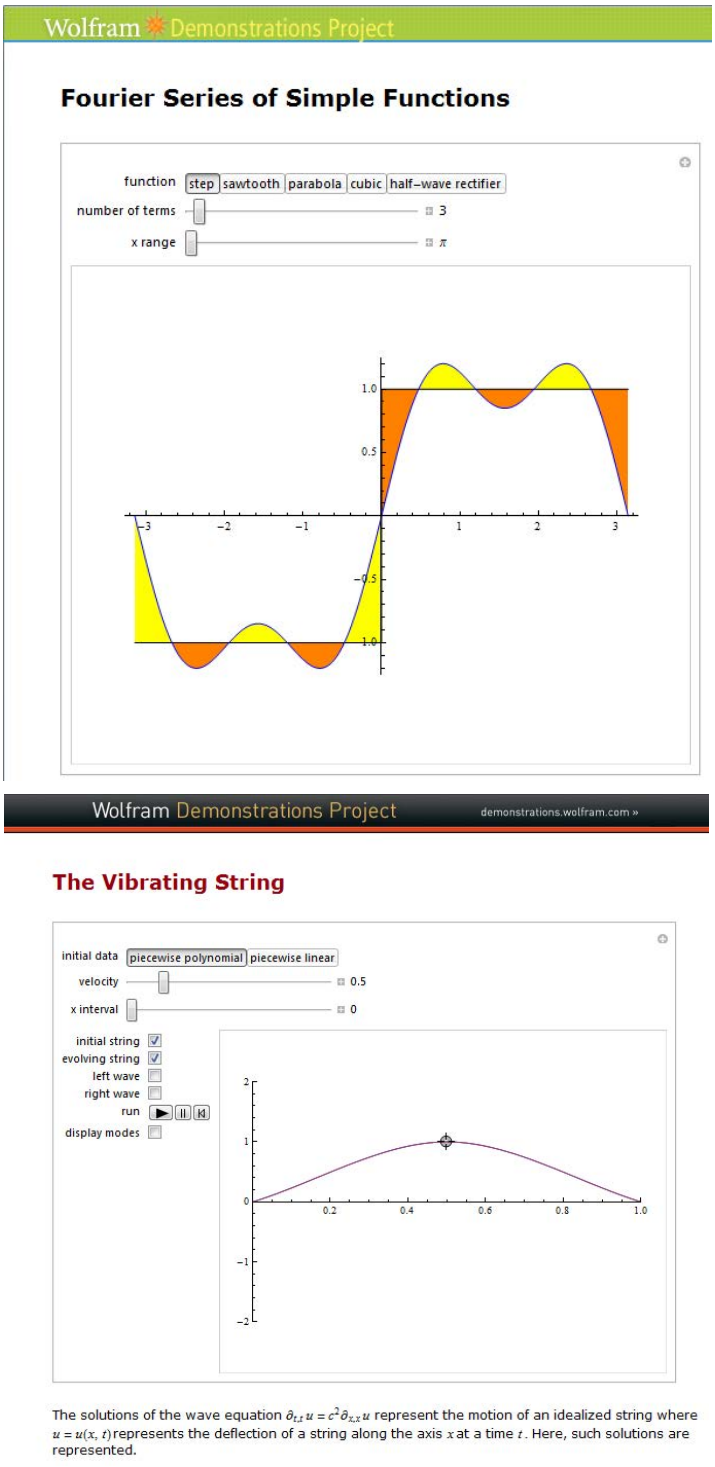


Figure 5. *WDP demos.*

To conclude this example, it should be stated that the number of demos we present for the topics covered by our subject is very large. We shall present only a few of them next. The files can be easily located in the search engine built into the WDP via their listed names. The extension of all these files is Mathematica Notebook (.cdf).

Topic 1: Multiple Integrals

- ApproximatingVolumesBySummation
- CavalierisPrinciple
- DoubleIntegralForVolume

- ExploringCylindricalCoordinates, ExploringSphericalCoordinates

Topic 2: Line and Surface Integrals

- IntegratingAVectorFieldAlongACurve
- VectorFieldFlowThroughAndAroundACircle
- TheDivergenceGaussTheorem
- ApproximatingTheLengthOfVivianisCurve

Topic 3: Differential Equations

- ForcedOscillatorWithDamping
- SeriesRLCCircuits
- PredatorPreyEquations
- ADifferentialEquationForHeatTransferAccordingToNewtonsLawOfC

Topic 4: Fourier Series

- FourierSeriesOfSimpleFunctions
- TheVibratingString
- ExamplesOfFourierSeries
- HeatTransferAlongARod

Topic 5: Complex Variable

- ContourIntegralAroundASimplePole
- TransferFunctionAnalysisByManipulationOfPolesAndZeros
- TransferFunctionFromPolesAndZeroes

5 CONCLUSIONS

The WDP resources, linked to specific content matter of the syllabus of each subject that are presented to students via the web platform, constitute an online teaching tool that complements face-to-face teaching, reinforcing the role of students as the central figures in the teaching-learning process and enhancing their autonomous development. The participation of lecturers from various departments is found to be a key aspect in enhancing transversal skills.

REFERENCES

[1] Mathematica http://www.wolfram.com/mathematica/

[2] Wolfram Demonstrations Project http://demonstrations.wolfram.com/

[3] Wolfram CDF Player http://www.wolfram.com/cdf-player/

[4] Bayón, L., Grau, J.M., Mateos, J., Ruiz, M.M. and Suárez, P.M. (2010). Aprendizaje interactivo en Matemáticas utilizando el Wolfram Demonstrations Project. Actas de CUIEET 2010.

[5] Bayón, L., Grau, J.M., Otero, J.A., Ruiz, M.M. and Suárez, P.M. (2011). Uso de herramientas de Software Libre para la enseñanza de las Matemáticas en los nuevos Grados. Libro de resúmenes de CUIEET 2011, pp. 68.