Innovative self-assessment and teaching/learning techniques for Calculus within the RIMA project (UPC-ICE)

M.R. Estela, J.Saà, J. Villalonga
Index

- Civil Engineering at ETSECCPB
- Mathematics for Engineers
- Innovative techniques for Calculus
  - Initial Math Subjects structure
  - Teaching/Learning Calculus resources
- Process Evaluation
- Conclusions
- Acknowledgments
Civil Engineering at ETSECCPB

Goal

• Prepare professionals who are able to adapt themselves to any business requirement and constant changes of the society, contributing to its sustainable development.

Challenges

• The European Higher Education Area (EHEA)
• Educational innovation
Civil Engineering at ETSECCPB

- Undergraduate degree
- Includes training in basic and applied science
- Mathematic subjects since the first year:
  - *Fundamentals of Mathematics*
  - *Calculus*
  - Algebra and Geometry
Maths for Engineering

- Troubles
  - Motivation
  - Enough time and effort
  - Difficulties to...
    - ...understand these mathematics
    - ...apply mathematics in engineering.
  - Academic results are not always so good.
Maths for Engineering

- Necessity to solve these troubles:
  - Revise the existing program.
    - New pedagogical model based on the EHEA
    - New basic Math subject: *Fundamentals of Mathematics*
  - Revise the existing teaching and learning tools.
    - Better and more adapted materials
Maths for Engineering

- Goals of initial Mathematics subjects (*Fundamentals of Mathematics and Calculus*):
  - Understand basic mathematics.
  - Increase motivation in mathematics.
  - Apply these mathematics in engineering.
  - Make, from mathematics, great and competent engineers.
Maths for Engineering

- **Academic Support**
  - give a greater visibility to innovative teaching
  - promote the participation of teachers in educational research and innovation activities.

- **Grimath**
  - unite efforts from all mathematic teachers of UPC who are interested in research and innovation in methods of learning mathematics.
Initial Math subjects structure

- Blackboard: real contact with students
- Continuous assessment + global exam
- Virtual Sites: more and easy subject information
  - UPC (Moodle) Virtual Campus:
  - ETSECCPB Platform:
Project development

- Since 2003:
  Developing and improving mathematical contents
  - Easy-reading and illustrative math textbooks and virtual books
  - Interactive exercises and laboratories.
  - ...

- In 2011:
  - Motivating contextualized videos
  - Innovative techniques: random tests and tutorships
  - Video Calculus workshops
Attending classes

- **Blackboard**
  - Basic tool
  - First explanations
  - Improvisations

- **Slides**

- **Interactive examples:**
  - change values & parameters in real time

- **Discussions**
  - exchange of views
Attending classes structure

If \( f(x,y) = \frac{x+y}{x-y} \), \( x \neq y \), with \( f(x,x) = 0 \).

In which directions the directional derivative of \( f \) at \( (0,0) \) exists?

<table>
<thead>
<tr>
<th>Answers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In any direction</td>
<td>9%</td>
</tr>
<tr>
<td>In no direction</td>
<td>48%</td>
</tr>
<tr>
<td>In the direction given by vectors ((a,b),</td>
<td>a</td>
</tr>
<tr>
<td>In the direction of the standard axis.</td>
<td>23%</td>
</tr>
</tbody>
</table>

- Televoting
  - Anonymous: more confidence
  - Global level of the class
Fundamentals of mathematics

- First contact with maths in the degree
  - Easy-reading basic math textbook
  - EVAM

Interactive applets to review definitions and mechanisms.
Fundamentals of mathematics

Resol el sistema i relaciona el rang de les matrius amb el resultat obtingut.

\[
\begin{align*}
\begin{cases}
x - y + 3z &= 7 \\
2x - 2y + 3z &= 11 \\
7x + 2y - z &= 9
\end{cases}
\end{align*}
\]

Resoldre

\[
A = \begin{pmatrix}
1 & -1 & 3 \\
2 & -2 & 3 \\
7 & 2 & -1
\end{pmatrix}
\rightarrow
\begin{pmatrix}
1 & -1 & 3 \\
2 & -2 & 3 \\
7 & 2 & -1
\end{pmatrix}
\]

\[
b = [7, 11, 9] \rightarrow [7, 11, 9]
\]

rang (A) \rightarrow 3

rang (A \mid b) \rightarrow 3

resoldre (A, b) \rightarrow [2, -2, 1]

Exercise to practice and check mechanisms and procedures.
Calculus

- Complete Calculus subject
  - General Calculus pleasant book with interactive support
    - Basic Calculus theory
    - Relation Calculus – Engineering
  - Calculus course on ATENEA
    - Interactive exercises and laboratories
    - Auto evaluating tests
  - ...
Calculus techniques

- Real examples of a Civil Engineering problem related with calculus.

![Image of forces on an airplane wing](image)

Figure 7.2: Fuerzas sobre las alas de un avión

Considering an element differential of the wing, by taking into account that the pressure force acting on that differential element will have a normal component \( N \) and a tangential component \( A \) to the element \( dl \), according to Fig. 7.3, a certain angle \( \theta \) with the components \( N \) and \( A \).

![Image of forces](image)

Figure 7.3: Fuerzas sobre las alas de un avión

Parametrizing with respect to the coordinate \( x \) the change

\[
d\cos \theta = dx d\sin \theta = -dy = -\frac{dy}{dx} \frac{dx}{d\theta}
\]

For the calculation to be made it is usually omitted the tangential tension

\[
\tau = 0
\]

More than theory: real applications
Calculus techniques

- Motivating contextualized videos: Expose an Engineering situation where a Calculus topic is essential.
  - Topics: Engineering and...
    - Topology
    - Numerical Series
    - Real Functions
    - Multivariable Functions
    - Riemann Integral
    - Function Series
Calculus techniques

Ejercicio 10.2.12.
La EDO \( \frac{dy}{dx} = f(x,y) \), \((x,y) \in \Omega \subset \mathbb{R}^2\), asocia a cada punto \((x,y) \in \Omega\) una dirección de pendiente \( m = f(x,y) \). Dibujar el campo de direcciones, las isoclinas y esbozar las curvas solución correspondientes a \( \frac{dy}{dx} = -xy \).

Solución 10.2.12.

Wide number of solved problems
Wording and developed solution in different windows
Objective: properly developing the solution of a problem
Calculus techniques

Wide variety of 2D and 3D (static and interactive) pictures and graphics which illustrate the theory
Calculus techniques

- Great variety of Virtual laboratories
  - Basic examples
    - modify default examples
    - edit particular problems
    - change parameters
  - Objective
    - discover and understand math properties
Calculus techniques

- Set of interactive exercises to self training
  - Displays:
    - different examples
    - validate the given solution
    - correct answers
    - accumulative scoring
  - Modify:
    - visualization
    - type
Calculus techniques

- Large collection of practice questionnaires
  - Distributed at the end of each unit.
  - Students see its own score: self assessment
  - Professors can see all the attempts and grades for student.
Calculus techniques

- Video Calculus workshops

A new block of videos which helps students to consolidate various calculus concepts through interesting math examples and explanations.
Continuous assessment

- Traditional writing problem solving
  - comments and revision

- Transversal problem (*multidimensional task*)
  - in small groups: team work
  - real situation: application
  - find the pattern: modeling
  - solve the problem: procedure & practice
  - new tools: Matlab
  - contrast solutions: relation
  - expose and defense the resolution: sociable skills
Continuous assessment

- Transversal problem (multidimensional task)

Ara en funció del radi de la boia i de la seva densitat:

\[ M = V_{\text{boia}} \cdot \rho_{\text{boia}} = \frac{4}{3} \pi r^3 \cdot \rho_{\text{boia}} \]

Si ara substituïm els valors de \( r \) i obtenim la massa en funció de \( \rho_{\text{boia}} \):

\[ M = \frac{32}{3} \pi \cdot \rho_{\text{boia}} \]

\[ -\frac{32}{3} \pi \cdot \rho_{\text{boia}} \cdot g + \frac{\pi r^3}{3} \left( 2 - \frac{3x}{2} + \frac{x^3}{8} \right) \cdot g = \frac{32}{3} \pi \cdot \rho_{\text{boia}} \cdot \ddot{x} \]

\[ \ddot{x} = g \left[ \frac{1}{4\rho_{\text{boia}}} \left( 2 - \frac{3x}{2} + \frac{x^3}{8} \right) - 1 \right] \]

Resolució amb Matlab

La sequència que s’hauria de posar en el Matlab:

```matlab
disp('Resolem l’equació d’una cadena que queda:')
pause(3)
disp('Utilitzarem la fórmula donada previament que queda:')
pause(3)
disp('Aplicant les condicions inicials de la solució del problema de valors inicials que queda:')
pause(3)
disp('-dsolve(''(D2x)-(9.8/10)*x''',''x(0)=0''',''(Dx)-(9.8/10)*x''))
```
Continuous assessment

- Virtual Moodle tests
  - Randomly generated
  - Questions randomly extracted from a data base.
- Contain formulas, graphics and pictures
- Automatic correction
- Without revision
Continuous assessment

- Tests with WIRIS Quizzes

Final unit tests
- Random exercises
- Random values
- Increase difficulty to copy

New training tests
- More variety of exercises
- Public and Restricted access from OCW

Comfortable for professors
- Program one activity: great variety of exercises
- Different languages (en, es, ca…)
- Automatic correction
Continuous assessment

- Grades of each student are collected in ATENEA:
  - Unit final tests
    - Virtual, problem solving, practicum…
  - Global writing exam
  - Students only see their own grades.
  - Professors have an immediately relation of all the grades and for each student.
Calculus questions

- FAQ Students:
  - In class
  - Traditional tutorships
  - By email
  - In a virtual lecture room: eConsultes

Elluminate + PaperShow
Techniques evaluation

- Students Opinion

Questions topics:
1. Use of the material
2. Easy access to the virtual course
3. Easy browse in the virtual course
4. Good organization of the material
5. Understandable explanations
6. Useful exercises
7. Useful laboratories
8. Useful solved problems
9. Useful final unit tests
10. Effective online tutorships
11. More complementary materials
12. Global score to the given material

Grades: 1 (bad or not used) - 5 (very good or very used)
Techniques evaluation

- Students Opinion

Global score for the material

Question 12

Cumulative % Frequency for each question
Techniques evaluation

- Students Opinion

‘All these interactive materials make it fun and easier to learn this subject! Sometimes you do not even feel you are working and in the meantime you are just learning a lot’.
Techniques evaluation

At the end of the course 2010-2011 statistics of the virtual platform confirms the opinion of our students.

<table>
<thead>
<tr>
<th>Specific moments</th>
<th>Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>During final exams, per day</td>
<td>600</td>
</tr>
<tr>
<td>Total, before hold final grades</td>
<td>123 343</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoevaluating tests</td>
<td>400 – 700</td>
</tr>
<tr>
<td>Solved Problems</td>
<td>50 – 300</td>
</tr>
<tr>
<td>Resource which displays a virtual laboratory</td>
<td>100 – 200</td>
</tr>
<tr>
<td>Resource which displays an interactive exercise</td>
<td>100 – 200</td>
</tr>
</tbody>
</table>
Techniques evaluation

- Instructors have really experienced a big improvement in the results obtained for the course.
- The average grade increased more than a 20% in just a few academic years.
Conclusions

- The given material and activities available:
  - Are friendly and allow students studying when they want.
  - Encouraged students to put more effort and time.
  - Help students to understand the topics of the subject better.
  - Help students to detect maths in engineering.

- To sum up, these tools...
  - Improve self-learning.
  - Consolidate concepts and procedures.
  - Are a good support for the traditional teaching on blackboard.
Acknowledgments

- Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona (UPC-BarcelonaTech)
- RIMA Project
- Institut de Ciències de l’Educació (UPC-BarcelonaTech)
- Agència de Gestió d’Ajuts Universitaris i de Recerca (Generalitat de Catalunya).
Thanks for your attention

M. Rosa Estela Carbonell
Matemàtica Aplicada III (UPC) - Grimath
m.rosa.estela@upc.edu

Joel Saà Seoane
Matemàtica Aplicada III (UPC) - Grimath
joel.saa@upc.edu

Joana Villalonga Pons
Matemàtica Aplicada III (UPC) - Grimath
joana.m.villalonga@upc.edu