INCREASING MEANINGFUL LEARNING OF ENGINEERING STUDENTS THROUGH ENABLING TECHNOLOGIES AND PRACTICES

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Abstract

Professionals of the 21st Century must be able to face the challenges of sustainable development through the capacity of effectively producing innovation. However, the fact that we are currently living in the information age does not imply that current graduates are smarter, have more knowledge nor that they can develop products, systems and services in a more efficient manner. This is even more critical in developing countries, where a rapid transition to greener economies following a self-established path, instead of blindly imitate industrialized nations, is a must. On the other hand, current technologies allow for a more profound impact in the learning process. With clear goals and proper implementations, ICTs can lead to more capable engineers. This work is a compilation of different technology-mediated learning experiences within the Mechatronics Engineering Program at the Universidad Piloto de Colombia. All of them consisted in a learner-centered approach, where the objective was to attain a considerable improvement in both hard and soft skills. A discussion of better ways to support learning with the presented tools is also carried out throughout this paper.

Keywords: ICT-mediated learning; learner-centered engineering education; student engagement

Resumen

Los profesionales del siglo XXI deben ser capaces de enfrentar los retos del desarrollo sostenible, produciendo innovación de manera efectiva. Sin embargo, el hecho de que nos encontremos en la era de la información no implica que los graduados actuales sean más inteligentes, tengan más conocimientos o que puedan desarrollar productos, sistemas y servicios de manera más eficiente. En países en vía de desarrollo esta situación es crítica *debido a la necesidad de seguir una ruta propia en la transición a economías verdes, en lugar de imitar ciegamente a las naciones industrializadas. Por otra parte, las tecnologías actuales permiten un impacto mayor en el proceso de aprendizaje. Con metas claras e implementaciones adecuadas, las Tecnologías de la Información y la Comunicación (TICs) pueden lograr ingenieros más capaces. Este trabajo es una compilación de diferentes experiencias de aprendizaje mediadas por tecnología en el Programa de Ingeniería Mecatrónica de la Universidad Nacional de Colombia. Todas ellas consisten en enfoques centrados en el aprendizaje donde el objetivo es lograr una mejora considerable de las habilidades sociales y disciplinares. También se anexa una discusión acerca de las mejores maneras en que se puede apoyar el aprendizaje mediante el uso de las herramientas presentadas.*

Palabras clave: *aprendizaje mediado por TIC, educación en ingeniería basada en el aprendizaje*

1. Introduction

If current and future engineering graduates are to meet the challenges of the modern society, they need to have a deep understanding of basic sciences and technical knowledge together with a set of 'soft' skills that allow them to devise solutions for the problems at hand. The Internet and today's information availability play a crucial role in providing professionals with the necessary tools for such challenges. Nevertheless, the actual impact of the information age on building a learning society has been topical and controversial. The bottom line is that universal access to information and novel technology alone are not a guarantee of avid engineers with improved skills.

In this work, new paradigms regarding learning processes, together with experiences in the classroom and the use of modern tools and technologies for engineering education are presented. The underlying principle of all these processes is that technology must serve pedagogy and not the other way round. The various methodologies were applied to different subjects of the Mechatronics Engineering curriculum at the Universidad Piloto de Colombia:

1. Chemistry
2. Materials Science
3. Renewable Energies
4. Technical English
5. Mechatronic Design
6. Engineering Design Management

2. Methodologies and Tools

Following a 'first-pedagogy-then-technology' approach, different learning experiences were developed and implemented in different lectures. The didactic techniques described below can be used in conjunction with others in order to achieve meaningful learning. Engagement and saliency are two essential factors taken in consideration for the application of these methodologies.

2.1. Serious Games

Games are perhaps the setting where learners can be focused for longer times with high levels of engagement. Team work and positive competition emerge during these activities, which make the classroom a more nurturing environment for learning. One of the biggest advantages of this approach is a substantial increment in learners' motivation due to the closeness of a reward (Cai & Goei, 2014; Kankaanranta & Neittaanmäki, 2009).

Figure 1. Kahoot("Kahoot!," n.d.) *is a free tool to create educative games.*

2.2. Simulations

Spatial reasoning has been key for engineering students acquiring concepts regarding forces, stresses mechanisms among many others. The more complex systems and concepts. Simulations allow students to experiment and see the results of different parameters within a physical setting. Another virtue of using simulations in learning is that, when correctly introduced, learners are more eager to understand the scientific concepts and mathematical tools that allow for the creation of such applications.

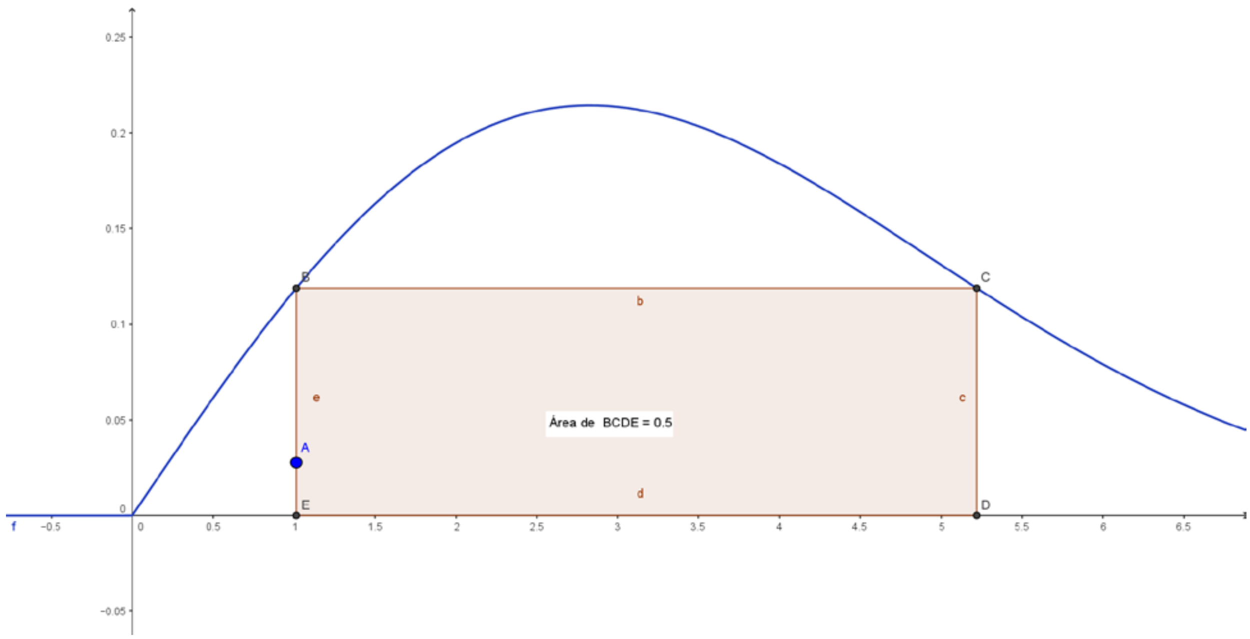

Figure 2. Optimization problem with dynamic mathematics Software GeoGebra (Bu & Schoen, 2015; Kaenders & Schmidt, 2011). *This example applies to the optimal design of wind energy systems*

Figure 2 depicts an application to the optimal design of wind energy systems. The blue curve represents the power distribution of a given place taking into account its wind regime. The larger the area of the rectangle beneath the curve, the higher the power output of the system. This optimization problem usually causes struggles for undergrad students. However, by using dynamic graphics the geometric interpretation of the problem is easier to understand, and it is also possible to arrive to the optimal solution in an interactive way.

2.3. Interactive Notebooks

Computational thinking requires the generation of structured processes. Interactive notebooks permit that the students document their own work and they serve as well as a valuable instrument for note taking during class and as a reference for homework. By organizing problem solving examples in an ordered, digital and editable manner, learners can review more easily their own work as well as explanations given in class. Besides interactivity, notebooks allow to combine text in between commands of definitions, making them a great companion for notetaking and further study.

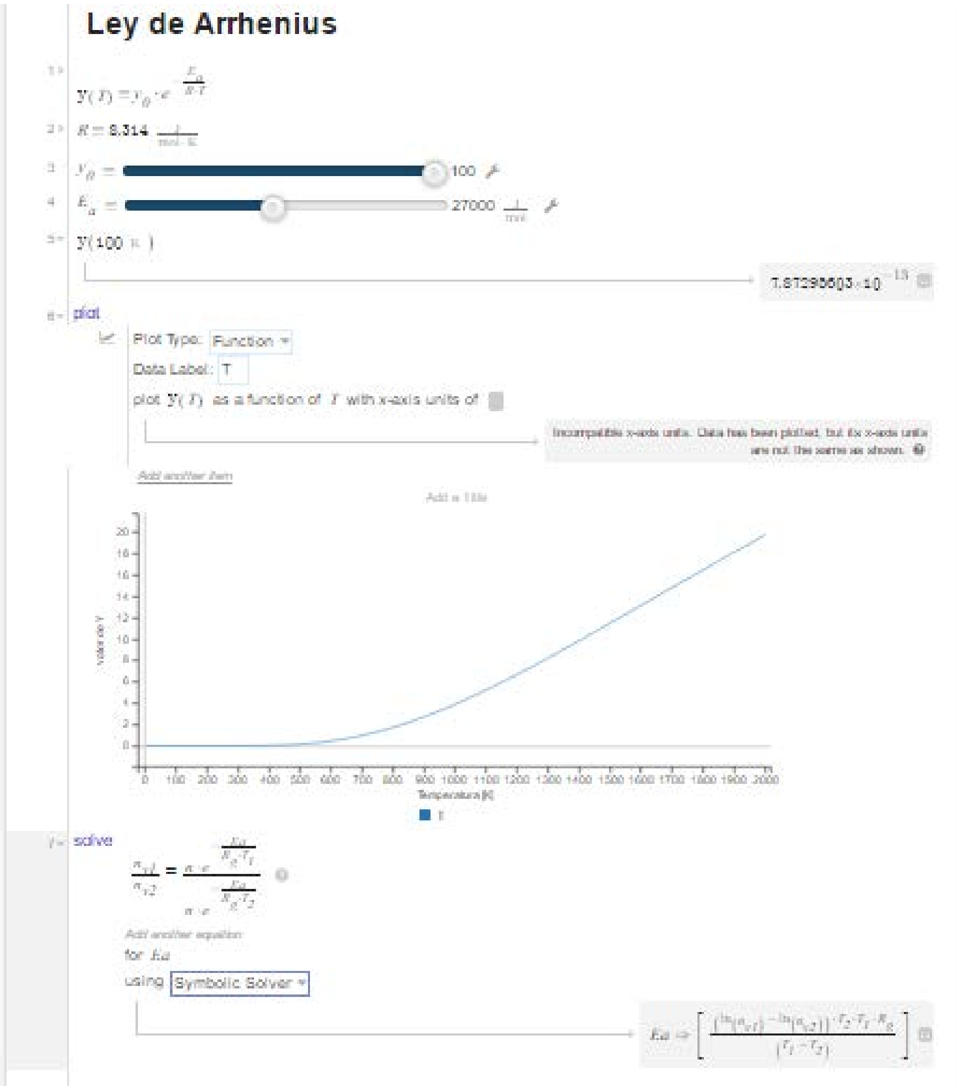

Figure 3 Interactive notebook made with SwiftCalcs

Figure 3 shows an example of an interactive notebook explaining Arrhenius's law. Line 3 and 4 of the notebook have sliders linked to the parameters of the equation. When changed, all the subsequent calculations are updated. This also applies for plots (line 6) so the behavior and effect of different parameters can be analyzed graphically. The notebook also provides a symbolic solver so that students in early semesters can verify and.

SwiftCalcs ("Swift Calcs," n.d.) has the advantage of being implemented completely online, requiring no local installation and being accessible from any computer with internet connection. Collaborative edition of documens is also possible, which is a common activity in the modern workplace. There are commercial alternatives like Matlab ® notebook(The MathWorks, n.d., 2012), wich consists in a plugin for word and allows for combining word Text with the Matlab Console. An open source alternative is iPython(Martins, 2014). This requires a valid python installation in the local machine.

2.4. Communication Tools

Mind and concept mapping, infographics can be used to promote and assess analysis, synthesis and oral communication skills. Wikis also allow for collaborative work without the need of the team members to be in the same physical space.

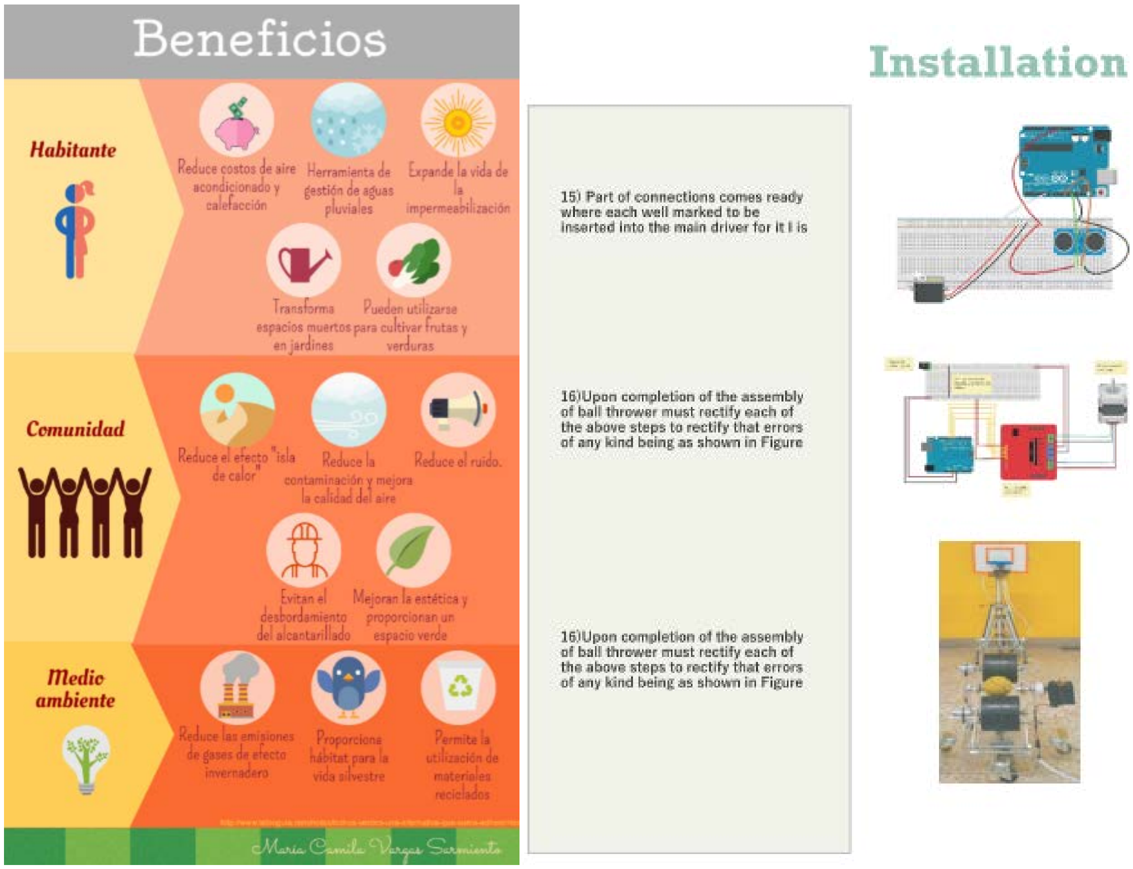

Figure 4. Left - Infografic about Green Roofs. Ellaborated by María Camila Vargas as homework for the elective course: Renewable Energies. Righ - Excerpt of user manual for a prototype. Elaborated by Edwin Gil during the Technical English course

These kind of knowledge representation combined with oral presentations are very useful tools for assessing in short times the depth of the research and the gained comprehension by the students. This kind of synthesis is essential in the contemporary world, where pressure for developing and producing novel products in shorter times is a must.

2.5. Project Management Approach

By providing learners with tools to measure, evaluate and improve their own projects as well as learners become more aware of planning as well as the importance of execution.

2.6. Local problems solving

In our industry, it is normal to see that local processes are changed in order to use a foreign machine. Changing this issue begins in our classroom by defining local problems. The students learn more about their environment through real Colombian problems and learn how to use their skills to improve their solutions. In order to create a machine to aid a process and not the other way, students develop commitment with society.

The problems are described as general needs, but the students need to identify all client requirements, for this reason they go and interact with the specific community. An example of this is when the students interact with farmers and ask them about the main issues when growing plants. They also ask to other professionals about their opinions of the proposed problem. These interactions with the society let them to have different points of view and to understand why is so important to create devices for our own needs.

2.7. Creativity awakening

Taking into account that every problem has its unique conditions and variables, students are highly encouraged to be creative and to be open to new ideas. They not only learn to listen to their peers but to merge several ideas in order to solve problems.

Different creativity strategies are shown and they have to choose among them and applied them to solve a specific problem. They are encouraged to think outside the box.

Although not always the students get goods ideas, they also learn how to make rankings, and evaluate which proposal is the best. They also learn to identify what are the advantages and disadvantages from the other ideas and so how to improve them.

The moto for creativity is "there are no bad or crazy ideas only poorly defined", taking this into account students learn how to stand up for their ideas by argumentation.

2.8. Self- and peer-evaluation

It is expected that students be evaluated by their professors but we have implemented an audit scheme for students by students. This scheme allows students to set the bar higher by noticing how far they can go.

This experience was very interesting since the students know that they can do better, in fact they know their own failures, and they try to improve their works prior to the peer-evaluation. The students that perform the evaluation learn to be objective, they learn to seek quality instead of quantity. This technic has also shown that some students were collaborative with each other to improve the outcome before the evaluation.

On the other hand, the real grade was assigned by teachers, this was made in order to avoid problems regarding the character of the students. Nonetheless, there was not reported any inconvenient during the semester.

2.9. Prototypes construction and validation

It is important to notice that there is a huge difference between sketching a solution than to really implement it. As mechatronics engineers they learn how to integrate (even to make synergy with) different technological structures in order to create a new device.

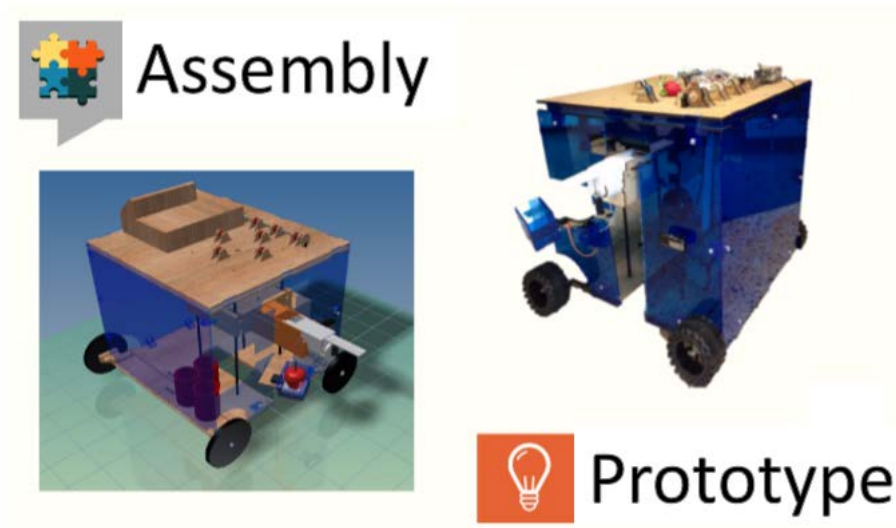

Figure 5. Prototype design and construction. This project was developed in Mechatronic Design by the students from CAJUPA team.

Figure 5 shows a pretty good approximation between the planned device and the prototype. This is what everyone should expect, but during the first times is not what really happens. With a proper guidance it is possible to help students to achieve their ideas and to construct them.

3. Conclusions and Future Work

The techniques presented here have shown to increase engagement in engineering students and they also point towards improvements in learning outcomes. More elaborated assessment methods are to be implemented in the future in order to determine the impact of these techniques on the professional performance of engineers. Among the skills that are mostly enhanced by these methodologies are: Data analysis and advanced used of spreadsheets; team working in virtual and asynchronous settings; algorithmic thinking and computer programming; leadership and team work; and last but not least, the learner's ability and desire to be in charge of her own learning process.

The role of engineering professors has evolved towards a manager of the learning process. It is their duty to keep themselves updated. In many cases, they have now the responsibility to teach learners how to learn. Novel tasks of engineering professors include: curation and generation of relevant content; development of interactive learning activities and applications; coaching of young engineers both in technical skills as well as communication and team work abilities. Ultimately, modern engineering teaching is only possible if professors are life-long learners equipped with the necessary technological and pedagogical tools that allow themselves and future engineers to innovate and transform society for good.

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