TEACHING INNOVATION PROJECT ON STRUCTURAL SOLUTIONS FOR HIGH VOLTAGE ELECTRICAL LINES USING 3D MODELING IN MECHANICAL ENGINEERING DEGREE PROGRAMS

J. Ferreiro-Cabello, E. Fraile-Garcia, M. Corral-Bobadilla, R. Lostado-Lorza, G. Villoslada-Villoslada

University of La Rioja (SPAIN)

Abstract

Based on our experiences conducting three teaching innovation projects over the past few years and the student surveys collected at the close of these projects, we can conclude that students are more interested in and motivated by dynamic classes that incorporate computer tools and other aspects from the structural calculation engineer’s professional experience. What’s more, students also greatly appreciate transversality across different subjects and degree programs. The present teaching innovation project focuses on the subject of Theory of Structures in the Mechanical Engineering degree program, in collaboration with other subjects from the same program, as well as from the Electrical Engineering department and a private sector business. The proposed activity is a 3D model of a tower for electrical networks, a structural analysis of the different components, and identification of the take-up rates. This activity is completed in groups (3 students per group) and supervised by the practical class teacher. Furthermore, as final cooperative task, a 3D mock-up is created by all the groups (the entire class). The objective of this project is for the student to experience the real-life challenges of an engineer. The goal is for students to develop and apply their capacities, abilities, attitudes, values and knowledge in realistic projects using modern and innovative resources. The group dynamic created by this hands-on work guided by the professor is much better than the traditional atmosphere of lecture-style classes. On a final note, students greatly appreciate dynamic and participatory classes. The student satisfaction survey completed at the end of this teaching innovation project offers feedback regarding the activities and how they can be improved.

Keywords: Teaching innovation. 3D printer, Structures, Electrical towers, Real models.

1 INTRODUCTION AND CONTEXT

During the third year of the Mechanical Engineering degree program in the Continuous Media Department, two classes are related to structural calculation. In the first semester, students study “Elasticity and Resistance of Materials” and in the second semester, “Theory of Structures”. Our aim is to conduct a teaching innovation Project (TIP) in the “Theory of Structures” class during the second semester.

To clearly demonstrate the motivation behind this TIP, let us briefly explain the TIPs we have undertaken in preceding years.

During the 2013-2014 school year, the TIP was called “EyRdM” and consisted of two interesting activities: spreadsheets created by students called “EfRdM Calculator” (their work is now available to the entire university community); and activities comprising problem-based learning, the case method, and discussion and debate. When this satisfactory experience came to an end, the project coordinator proposed giving students a satisfaction survey where they could offer feedback on the activities they had completed. The students responded positively to the activities realized, and made specific observations about the different activities. For instance, many students requested working with real-life professional problems. This TIP did not include this type of problem as it focused primarily on developing and creating the EyRdM calculator.

During the 2014-2015 school year, a teaching innovation project called “Integrating transversal content and a professional focus in the Theory of Structures” was implemented. The most noteworthy activity was carried out by teams of students and consisted of just one task with a professional nature. After completing the structural analysis, wherein the theoretical concepts covered in class were applied, each group conducted an economic evaluation of technically viable solutions and analyzed their environmental impact. With the goal of analyzing and improving the TIP activities, students were
asked to complete a survey at the close of the project. The “professional” activity received 4.11 points out of 5 from students, which reaffirms their interest in this sort of task.

During the 2015-2016 school year, the teaching innovation project “Feedback & 3D Printer” included three activities. The first involved creating teaching materials for the theoretical component of the Inverse Methodology class. The second activity involved handling, checking and expanding the EyRdM calculator created during the 2013-14 TIP. The third activity consisted of using a 3D printer to create scaled structural details of industrial construction. These three activities generated educational materials for future courses. Based on students’ responses to the satisfaction survey, it was decided that the questionnaires would continue to be used but that the Inverse Methodology would be eliminated. The EyRdM calculator and the details created by the 3D printer are still available to students and professors upon request. The activity to receive the most positive feedback was the 3D construction solutions.

Given these past experiences, we are fully aware of how difficult it is to boost student motivation. After analyzing the results of the student surveys from the past teaching innovation projects, it should be noted that professional-like activities and innovative technologies (3D printers) significantly fostered students’ motivation and interest in the subjects in question. Classic teaching styles have evolved. Nowadays, educators have access to a wide range of tools that can enrich their classes. One of these tools is the 3D printer, which is increasingly present in educational contexts (1). 3D printers offer a diverse range of applications for teaching in general (2) (3) and particularly in engineering (4). The pedagogical benefits of 3D tools are well-documented (5). 3D technology has been utilized in an array of experiments in different fields, such as chemistry (6), biology (7), special needs education (8) and surgery (9). All of these studies demonstrate the enormous potential of 3D printing tools.

As educators, we are obliged to adapt ourselves and our teaching styles to new technological horizons and incorporate new tools. Therefore, educators should motivate students by planning dynamic classes with a professional feel. Third year students must begin to truly master the competencies necessary to exercise their future profession. Hence, this teaching innovation project is designed to give students a taste of their future professional reality. What’s more, the interest students exhibited in professional computer tools in past TIPs, as a way to build upon their knowledge, has impelled us to use these tools to design and manufacture products (10) (11).

Capturing and keeping students’ attention sets the teaching-learning process into motion. When students are truly engaged, work inside and outside the classroom becomes more enjoyable and productive for students and for teachers, as well. Based on the foregoing, this project aims to incorporate another aspect that is vital to engineering degree programs: transversality. The present proposal involves collaboration between the departments of Mechanical and Electrical Engineering. Thus, the TIP is planned for the Theory of Structures class is called: “Structural Solutions for High Voltage Electrical Lines using 3D Modeling”.

## 2 OBJECTIVES

This teaching innovation project has objectives that are general and specific, as indicated in Table 1.

<table>
<thead>
<tr>
<th>General Objectives</th>
<th>Specific Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students and professors engage in a teaching methodology focused on independent learning.</td>
<td>Use computer tools and critical evaluation of results obtained.</td>
</tr>
<tr>
<td>Students acquire new work habits involving computer tools.</td>
<td>Experience with regulations in the field of structures and other areas of engineering.</td>
</tr>
<tr>
<td>Facilitate independent and proactive learning, wherein the professor guides and supports students.</td>
<td>Strengthen the teaching-learning process through feedback obtained during consultations.</td>
</tr>
<tr>
<td>Students are willing and eager to tackle challenges in Structural Engineering.</td>
<td>Students come into contact with real-life solutions from the industry.</td>
</tr>
<tr>
<td>Foster the use of new communication technology between students and teachers.</td>
<td>Teaching based on experiential learning with 3D models.</td>
</tr>
</tbody>
</table>
3 PROPOSED METHODOLOGY

The methodology proposed herein aims to fulfill the following innovation goals of the University of La Rioja: “Incorporate active methodologies that facilitate the development of general and specific competencies and that increase the students’ motivation to learn”, and “Create new tools and educational materials to be used inside and outside the classroom”. Meanwhile, the European Area for Higher Education proposes: quality based on applying new techniques or instruments in education planning and evaluation; fostering diversity by addressing issues transversally, which leads to a wealth of ideas and new ways of analyzing and tackling real world problems; competition to acquire the capacities of structural engineering.

Thus, the proposed activity focuses on the abovementioned class within the context of the third year of a Mechanical Engineering degree program. The present teaching innovation project consists of two activities differentiated by the characteristics of the specific subject, but also complementary:

- 3D modeling of an electrical transmission tower. Structural analysis of the different components and identification of the take-up rates. This activity is completed in groups (3 students per group) and supervised by the practical class teacher.
- The final task is cooperative: a 3D model is created by all the groups together (the entire class).

In order to adapt the problem statements/formulations to the number of groups (estimation: 15 groups), a mechanical calculation of a high voltage electrical line is realized which will include as many transmission towers as groups of students. This way, the activity can be adapted to the actual number of enrolled students. The figure below shows an example of high voltage lines.

![Figure 1. Example of a transmission tower for high voltage networks.](image)

This calculation indicates the charges corresponding to each phase and for each hypothesis posited by regulations. These charges are specific to each tower, and thus problem statements/problem formulations for each group are obtained. The statements include a solution from a commercial catalogue of transmission tower dimensions and their corresponding foundation. Each group, based on their statement, must create a model tower with the 3D Structural Analysis tool CYPE. This task is designed to evaluate the structural take-up rates of the different elements, including the foundation. This task is the first activity of structural modeling. Completing this task successfully constitutes 75% of the project's final grade.

For the second activity, all the students must work cooperatively to create a 3D model of the high voltage line. All possible graphic information is obtained from the structural modeling system and incorporated into the specific software that is used produce the pieces with a 3D printer (see Figure 2). Upon completion of this task, all groups receive the same grade which constitutes 25% of the project's final grade.
This calculation indicates the charges corresponding to each phase and for each hypothesis posited by regulations. These charges are specific to each tower, and thus problem statements/problem formulations for each group are obtained. The statements include a solution from a commercial catalogue of transmission tower dimensions and their corresponding foundation. Each group, based on their statement, must create a model tower with the 3D Structural Analysis tool CYPE. This task is designed to evaluate the structural take-up rates of the different elements, including the foundation. This task is the first activity of structural modeling. Completing this task successfully constitutes 75% of the project's final grade.

For the second activity, all the students must work cooperatively to create a 3D model of the high voltage line. All possible graphic information is obtained from the structural modeling system and incorporated into the specific software that is used produce the pieces with a 3D printer (see Figure 2). Upon completion of this task, all groups receive the same grade which constitutes 25% of the project's final grade.

The product created by the 3D printer facilitates a more in depth visual examination. This experience can be shared with other classes dealing with the mechanics of continuous media, and with other areas or departments, such as Electrical Engineering.

Once the activity is completed, an analysis is conducted of the results obtained in the evaluation. This analysis indicates if the proposed objectives have been fulfilled. A study survey is also conducted (Figure 3). This survey consists of two different sections depending on the type of information to be gathered. One section gauges the suitability of the proposed activity, and the other seeks out students’ concerns and suggestions for improvement.
It should be noted that computer tools foster and promote implementing dynamic teaching proposals. What’s more, computer tools allow students to engage in experiences that realistically simulate their professional futures as structural engineers. This project is also remarkable for its transversality: information is connected across different software packages (which will soon be possible via Building Information Modeling, BIM).

### 4 PROJECT PLANNING AND TIMELINE

Firstly, sizing and the mechanical calculation of the high voltage line to be used in the statements must be completed. This task is carried out in close cooperation with the Electrical Engineering department and a private sector business (IMEL S.L.). Students are introduced to the solution for the proposed high voltage line by technicians from the collaborating company. The number of towers corresponds to the number of groups of students plus one. This additional statement is designated statement_0.

The classes introducing students to structural analysis tools utilize statement_0 as an example, which is distributed at the beginning of the practical classes. A few practical classes are dedicated to statement_0 (5 weeks). Students are required to write up reports on the practical classes to confirm that they have assimilated the concepts covered in class. Another set of practical classes is dedicated to addressing each group’s specific statement (6 weeks). Regarding this final part, students are required to submit a report for evaluation. During the last four weeks, classes are dedicated to creating the 3D model. The table below summarizes the timeline.
Table 2. Timeline of teaching innovation project.

<table>
<thead>
<tr>
<th>Week 1 31-01-2017</th>
<th>Week 15: 15-05-2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 days</td>
<td></td>
</tr>
<tr>
<td>Develop statements</td>
<td></td>
</tr>
<tr>
<td>Activities statement_0</td>
<td></td>
</tr>
<tr>
<td>Evaluation statement</td>
<td></td>
</tr>
<tr>
<td>Activities group’s statement</td>
<td></td>
</tr>
<tr>
<td>Evaluation group’s statement</td>
<td></td>
</tr>
<tr>
<td>3D model</td>
<td></td>
</tr>
<tr>
<td>Analysis of results</td>
<td></td>
</tr>
<tr>
<td>Student surveys</td>
<td></td>
</tr>
</tbody>
</table>

The class professor is responsible for tracking the activity’s progress, and the head of the teaching innovation project is responsible for coordination. Both parties collaborate on developing the statements and planning the activities. During their meetings, the scope of the student reports is established. The class professor evaluates the students’ reports, whereas the results are analyzed by both the class professors and the head of the TIP.

The 3D model is evaluated jointly by all project participants. The analysis activities indicate if the competencies and established objectives were reached during the activity. Once the activity has come to an end, the results of the analysis are complemented by the information gathered in the student survey.

5 EXPECTED RESULTS

The expected results of this teaching innovation project are summarized below:

This methodology presents an opportunity for students and professor to collaborate. The students ask and receive answers to their questions in class, and sometimes students are able to answer other students’ questions. This dynamic encourages students to express themselves and speak up in public.

The objective of this project is for students to experience the real-life challenges of an engineer. The goal is for students to develop and apply their capacities, abilities, attitudes, values and knowledge in realistic projects using modern and innovative technology.

When students enter the work force they should be capable of responding to the situations they encounter.

The group dynamic created by this system (of guided hands-on work including feedback) represents a significant improvement over the traditional atmosphere of lecture-style classes.

Students greatly appreciate dynamic and participatory classes. The practical classes are exceptional learning opportunities as they make constant reference to the problem to be solved, thereby capturing and maintaining students’ attention.

6 CONCLUSIONS

This teaching innovation project allows students to experience the real world challenges encountered in engineering, and motivates them with the latest computer tools, such as 3D printers. When students take part in realistic activities, they develop their capacities, abilities, attitudes, values and knowledge by using modern and innovative technology.
The project impels students to improve various competencies: “Capacity for analysis and synthesis. By using 3D models, as proposed in this TIP, the difficulties that often arise with 2D models are overcome”, “Ability to apply knowledge in practice. Checking work completed by another person, a task to be done at the beginning of the course as indicated in the TIP”, and “Planning and time management and the ability to work independently. Being responsible for checking one’s work independently, with a set deadline, encourages students to acquire this competency.”

Students tackle this project almost completely independently (they receive some guidance from their professor), and in doing so they demonstrate their ability to respond to realistic situations. On a final note, students greatly appreciate dynamic classes where they play a leading and active role. This type of teaching practice truly captures students' interest and attention.

ACKNOWLEDGEMENTS

We would like to acknowledge the support received from the Vice-Rector of Faculty, Planning and Teaching Innovation through their teacher training and innovation programs at the University of La Rioja. We would also like to express our gratitude for the collaboration of the electrical installation company: IMEL, Instalaciones y Montajes Eléctricos Logroñeses S.L.

REFERENCES