TEACHING INFRASTRUCTURE MAINTENANCE MANAGEMENT THROUGH INTERDEPARTMENTAL COLLABORATIONS

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Abstract

Infrastructure comprises any facility that provides services of transportation, energy, water supply and housing. The ability to construct and properly maintain infrastructure systems is essential to ensure the economic development, competitiveness and productivity of nations. Thus, trillions of US dollars have been invested over the past decades to maintain the global infrastructure assets. Because of that, teaching infrastructure maintenance is increasingly a key issue in any university degree focused on civil engineering. In order to satisfy the demand from the construction industry, the School of Civil Engineering at the Universitat Politècnica de València has created a course entitled "Infrastructure Maintenance Management" in the fourth academic year of the B.Sc. in Civil Engineering. This transversal course has been created through an interdepartmental collaboration to train students about integrated maintenance management in each of the different type of infrastructure. The course is divided into general and specific modules. The general module has been defined to offer students the needed knowledge to face the technical specifications provided in the different specific modules associated with each type of infrastructure. Different training techniques have been used in this course focused on individual and collective learning techniques through case study scenarios, small group workshops and presentations, all of them supervised by experts. This course allows the students to be aware of the importance of infrastructure maintenance in order to make decisions regarding the identified needs and the resources available.

Keywords: Interdepartmental collaborations, infrastructure maintenance, collective learning techniques, workshops.

1 INTRODUCTION

Infrastructure provides the foundation on which we carry out our everyday activities and contributes to citizens' overall quality of life [1]. Trillions of US dollars have been invested over the past decades to build the global infrastructure asset base and, every year, US$ 2.7 trillion is invested in new infrastructure [2]. However, the supply of new infrastructure cannot keep pace with demand and the growth of the infrastructure asset base is failing to keep up with society's needs [2]. Many countries have limited revenues to address aging infrastructure and a gap exists between the funding required to address infrastructure needs and funding available to do so. Across all sectors of economic and social infrastructure, the global infrastructure investment gap amounts to at least US$ 1 trillion per year. This corresponds to about 1.4% of global GDP. On the other hand, much of the existing asset base is wearing out since many of the European Union (EU) and United States (US) infrastructures were built in the 1950s-1970s, and many of them are either reaching the end of their expected lifespans, or becoming structurally deficient and functionally obsolete. For example, the average age of the 607,380 bridges in the US is currently 42 years, and that of the 84,000 dams is 52 years. According to the American Society of Civil Engineers, the investment needed to improve the condition of the American infrastructures was quantified in 3.6 trillion dollars [3]. In Germany, about a third of rail bridges are over 100 years old [2] and in Spain the condition of road infrastructure was assessed as deficient in 2016, requiring 6.6 billion of euros to maintain the infrastructures [4].

Currently, cost of operation and maintenance may represent up to 90% of the total life cycle costs on infrastructure [5] and, until recently, most of the infrastructure owners ignored the cost of operation and maintenance at initial stages of the infrastructure life-cycle [6]. Thus, since one of the main functions of a civil engineer is to plan, organize and supervise maintenance and repair work on existing structures, teaching infrastructure maintenance is increasingly a key issue in any university degree focused on civil engineering [7-9]. In order to satisfy the demand from the construction industry, the School of Civil Engineering at the Universitat Politècnica de València, after the development of numerous educational researches [10-14], have created a course entitled "Infrastructure Maintenance Management" in the fourth academic year of the B.Sc. in Civil

Engineering. The course is within the module “complementary training” and it comprises 4.5 ECTS. The main goals of the course are:

- Introduce the student to technical and managerial aspects of infrastructure management.
- Provide the vocabulary and terms used to the students that are usual in infrastructure maintenance management.
- Lay a foundation for identifying and implementing strategies, processes and tools to optimize decision-making and investment planning.

1.1 Educational Objectives

The objectives of the course “Infrastructure Maintenance Management” are:

- Analyze from a critical perspective the civil engineering processes.
- Encourage students to learn on their own new knowledge and adequate techniques for civil engineering.
- Prepare students scientifically and technically to perform the profession of civil engineering with skills of consultancy, analysis, design, construction, maintenance and operation.
- Maintain, conserve and operate infrastructures.
- Communicate efficiently, in both, in a written and oral way, knowledge, procedures, results and ideas related to civil engineering.
- Acquire knowledge and understand the science and technology corresponding the planning, design, construction and operation of civil engineering works.
- Maintain and conserve the hydraulic and energetic resources.
- Understand and use both the professional language and terminology of civil engineering.

1.2 Contents

The course has been created to train students about integrated maintenance management in each of the different types of infrastructure. For this reason, an interdepartmental collaboration has been needed between three different departments of the School of Civil Engineering at the Universitat Politècnica de València in order to offer a comprehensive view of the needs of maintenance and how to manage it. These departments, and their areas, are:

- Dept. of Transportation Engineering (including the areas of highways, railways and ports),
- Dept. of Hydraulic Engineering and Environment (including the areas of sewage network, water supply, hydraulic infrastructures and hydroelectric power plants), and
- Dept. of Construction Engineering (including the areas of bridge construction, building and construction project management).

The course is divided into two modules: (1) a general module aimed at offering students: the necessary knowledge to understand the need of infrastructure maintenance, the key aspects in maintenance management and the protocols of infrastructure management and maintenance; and (2) a specific module composed by a group of topics focused on particularizing the general concepts that can be applied to the different types of infrastructures.

The topics of the course are grouped as follows:

- Module 1: General. Introduction and common aspects. (1.87 ECTS)
  1.1. General concepts of maintenance and life cycle of infrastructures.
  1.2. General procedures of inspection and auscultation techniques.
  1.3. Integrated maintenance management: goals and policies, inventory, condition assessment, performance modeling, assessment and optimization, short and long term plans, program implementation, performance monitoring.
- Module 2: Specific. Particular aspects. (2.63 ECTS)

2.1. Maintenance of transportation infrastructures: highways, railways, maritime and port infrastructures.

2.2. Maintenance of hydraulic infrastructures; water supply, sanitation systems and large-scale hydraulic works.

2.3. Maintenance of buildings.

2.4. Maintenance of bridges.

Module number 1 is taught by only one instructor; however, in the module number 2, nine different instructors participate.

2 METHOD

Different methodologies have been used in this course focused on individual and collaborative learning techniques:

- Lectures: Instructors teach the theoretical basis through lectures in class. In these sessions, the topics are explained and questions are proposed to the students.
- Individual and in-pairs activities: Practical activities are proposed by the professors to be solved in class time throughout the course. Depending on the activity, these have to be solved individually or in pairs. These activities are based on knowledge tests, case studies and studying scenarios in order to consolidate the knowledge and ensure their understanding. At the beginning of the activity, students have to solve these activities in class without the support of an instructor during limited time. Finally, the instructor solves them in cooperation with the students. These activities are carried out in class time to enhance the learning and to boost the motivation. Additionally, the attention in class and the level of understanding is controlled through gaming techniques with the use of smartphones such as quizzes, surveys and discussions in real time. Case studies are performed to achieve a deeper level of analysis, implementing the theoretical bases in real cases and hypothetical scenarios.
- Collective activities. Groups of two or three students are formed to carry out workshops at the end of the course. A professor of each area of expertise proposes a specific case study to be solved by one group of students supervised by an expert. Finally, each group of students prepares a detailed presentation to show the case study and how they have solved it. These workshops allow students to share the acquired knowledge, showing the in-depth study. Through the study and analysis of real cases, students achieve a better conscience about the importance of an appropriate maintenance management.

  Some examples of the cases studies analyzed are:

  - Maintenance management of the Valencia's bridge "El Puente de las Flores".
  - Maintenance plan of the cable-stayed bridge over the Turia river.
  - Alameda Metro Station maintenance and conservation plan.
  - Maintenance management of the area of public moorings in the port of Denia.
  - Maintenance and conservation of the "Estación del Norte" (old main railway station in Valencia).
  - Maintenance management of the hydroelectric complex of "Cortes-La Muela".

  The aspects to be developed in each case study are:

  - Introduction.
  - Description of geometry and structure.
  - Proposal of inventory to manage the maintenance of the structure.
  - Condition indicator study.
  - Analysis of current and potential damages.
  - Monitoring plan.
  - Maintenance schedule.
  - Conclusions.

3 ASSESSMENT

The assessment is based on three factors which are evaluated independently:

- Two objective tests related with each module:
  - Test E1, associated with the module 1, represents the 40% of the final mark.
  - Test E2, associated with the module 2, represents the 20% of the final mark.
- The final case study (P) constitutes the 40% of the final mark. The 60% of this evaluation depends on the content of the report and the other 40% is associated with the oral presentation. Two different rubrics are used in order to assess the results objectively (table 1 and table 2). Table 1 shows the rubric for the oral presentation assessment and Table 2 shows the rubric for the evaluation of the content of the report. In both, the marks obtained with these rubrics were normalized in order to establish the range between 0 and 10.
- The obtained mark can be modified with a correction factor (A) which takes into account the attitude and active participation of each student in class. This correction factor is between 1.2 and 0.8 and it is defined according to the results obtained by the students in the individual and in pairs' activities.

The final mark is obtained through the following expression: (E1*0.4+E2*0.2+P*0.4)*4≥5.

Table 1. *Rubric for the oral presentation assessment*

Score	1 point	2 points	3 points
Criteria	Level 1	Level 2	Level 3
Level of experience	Lack of clarity and consistency	Occasionally the ideas are expressed clearly	All the ideas and details are expressed clearly and with fluidity
Confidence during the exposition	Lack of confidence during the exposition	Sometimes the confidence is shown during the exposition	The student shows a lot of confidence
Vocabulary	Only limited vocabulary is used. Words repetition	Only limited vocabulary is used.	Wide vocabulary. No words repetition
Personal opinion	Personal opinion is not given	Personal opinion is not clear	Personal opinion is given
Material	Material of the exposition is not provided	Material of the exposition is provided of bad quality, bad use o without using it	Material is provided and used in a presentation of good quality
Voice	Not clarity in the speech	The speech is clear but not always easy to listen to	Strong and clear voice. Easy to listen to
Body position	The student does not stand straight and does not look at the audience	Occasionally, the student stand straight and look at the audience	The student stands in good body position

Table 2. *Rubric for the evaluation of the content of the report*

Criteria (maximum value)		**Score**
Structure and content (40)	Index (5)	
	Body of the report (25)	
	Conclusions (5)	
	References (5)	
Writing and formal aspects (20)	Adequacy (5)	
	Fluidity and vocabulary (10)	
	Format (5)	

4 RESULTS

Taking as an example the groups of students in the academic years 2016-2017 (15 students) and 2017-2018 (17 students), Fig. 1 and Fig. 2 show the obtained results for each type of work (E1, E2 and P) in each academic year.

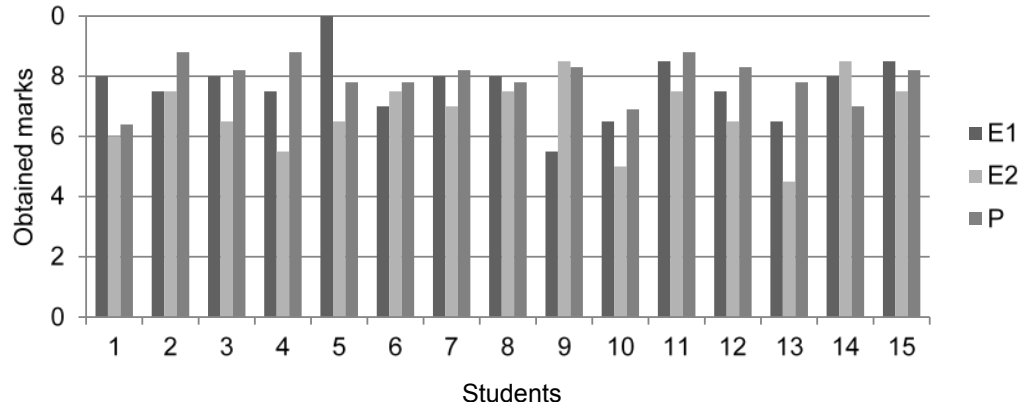

Figure 1. Results obtained by students in the academic year 2016-2017

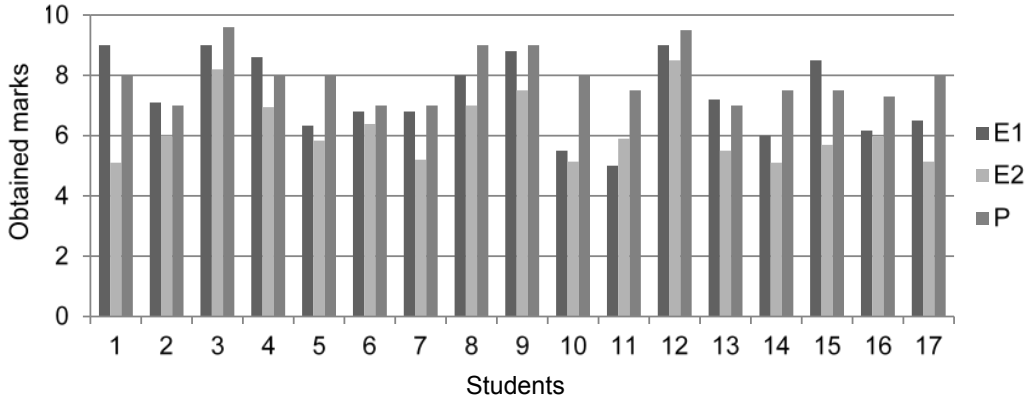

Figure 2. Results obtained by students in the academic year 2017-2018

Fig. 1 and Fig. 2 show that the results were lower for the E2 test respect to the E1 test in both academic years. The averages for the academic year 2016-2017 were 7.6 in the E1 and 6.7 in the E2; and in the academic year 2017-2018, the E1 average was 7.2 and E2 average was 6.1. This was due to the fact that: (a) there was a difficulty associated with the particular implementation of the concepts of the first module in each type of infrastructure, (b) a greater number of professors participate in the second module resulting in poorer outcomes and (c) the lack of individual and in pairs activities in the second module implied lower results. However, the marks of the final Case studies (P) for both academic years were high in comparison with the results of the test E1 and E2. This was due to the close collaboration between students and expert professors which allowed clarifying and consolidating concepts to be applied correctly in the maintenance management of the infrastructures, overcoming the shortcomings found in the test E2.

5 CONCLUSIONS

The main conclusions of this experience are the following:

- Interdepartmental collaboration is needed in order to teach a comprehensive approach about infrastructure maintenance management.
- Individual and collaborative activities during the course are important to control the students' progress and the degree of understanding acquired in class.

- Close collaboration between students and professors through the development of case studies allows achieving a deep understanding and the assessment real scenarios in order to give students a glimpse into the world of work.

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