IMPLEMENTING DESIGN THINKING METHODOLOGY IN MINING ENGINEERING DEGREE

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Abstract

The application of new learning methodologies in subjects related to engineering is required for students to develop their transversal skills, such as teamwork, creativity, problem-solving and the development of scientific thinking. On this account, Design Thinking was applied in the Mining Resources Prospecting module of the bachelor's degree in Mining Engineering at the University of Oviedo (Spain). The execution of a geochemical study in the surroundings of a closed mercury mine has been proposed to the students, from the conception of the project on paper to the sampling survey and the statistical treatment of the data. Thus, the first two phases of the methodology, empathise and define, were specified by the teaching staff, and the students developed the following phases: ideate, prototype, and test. The results revealed that the students' satisfaction with the module increased due to the direct application of the knowledge acquired, the scope of teamwork and the satisfaction of overcoming an engineering challenge.

Keywords: Design Thinking, mining, problem-solving.

1 INTRODUCTION

The transformation of education in European universities demands new abilities in students. With this purpose in mind, changes in the ability design as well as the development of new learning methods and tools are required [1 – 4]. With regard to engineering education, the implementation of teaching techniques and methods which allow students to achieve the necessary skills to solve real engineering problems is of crucial importance [5 – 6]. Classical approaches, such as the resolution of numerical exercises, are not efficient enough to create all the skills necessary for students to solve real engineering problems [7]. Several techniques aim at solving this problem [8], among them, Design Thinking (DT) is one of the most popular.

Although Design Thinking appeared in 1960’s it is a method which has emerged over the last few years [8]. Although there are several lines of study, all concur in a first exploratory analysis of the problem, followed by a convergence on a solution reached by teamwork. The development of teamwork and other transversal skills is required for the students to obtain the abilities required for the job market. In this way, many authors indicate that although higher education provides them with technical knowledge, students should be able to acquire skills such as problem solving, creativity, communication and teamwork [9 – 10]. Thus, the DT method has been regarded as an efficient tool for resolving engineering problems and for project management training [11].

Following the preceding considerations, in this work, the DT method was applied in order to propose a real problem to the students related to the scope of the Mining Resources Prospecting module of the bachelor’s degree in Mining Engineering at the University of Oviedo. The aims of this activity were to promote the use of transversal skills such as teamwork and communication tools by means of the practical applications of the theoretical knowledge explained throughout the module, specifically mining and environmental issues.

2 METHODOLOGY

According to Dorst [12], the methodology comprises of five stages: empathize, define, ideate, prototype and test. The first and second stages of DT are related to understanding the customer and defining the problem. Therefore, the professors (Fig. 1) have previously partly defined these stages. The problem stated consisted of performing an environmental study in the surroundings of an abandoned mercury mining area with the aim of delimiting the affected area (mainly arsenic) but also...
mercury. La Soterraña mine was one of the most important mercury mines located in Asturias (Spain) and pollutant emissions and dumping of wastes affected the surrounding areas [13 – 14]. After the closure of the facilities, no restoration measurements were performed.

The tools necessary for the development of the study were explained to the students in the first lectures using theoretical expositions and similar case-study examples. Moreover, at the third stage of the DT methodology (ideate, Fig. 1), the students were confronted with the design of a geochemical campaign in the study area. In order to facilitate the design, detailed cartography of the area was provided to each student. The students were asked to provide an individual proposal. These proposals were discussed with the professors and a final approach was defined and represented by means of a Geographic Information System (GIS), this was also useful to introduce the students to the use of these types of software and databases.

The prototype step was carried out by the specific fulfillment of a sampling campaign (Fig. 1). The required methods for the sampling were explained and the students took the samples while at a site survey (Fig. 2). This visit was also used for a better understanding of the real-scale problem and also to explain different concepts on occupational safety and health. Once all samples were taken, their preparation was performed at the laboratories of the University of Oviedo using standard methods that were previously explained and shown to the students. The students air-dried the samples, sieved them, discarding grain sizes >2 mm and milling the smaller sizes. Finally, the samples were analyzed at the laboratory by portable X-ray fluorescence equipment. In this last case, the students also performed the preparation of the samples, although the analyses were performed by the supervisor of the radioactive installation according to the legislation.

Finally, the last stage of DT consisted of interpreting the data (“test”, Fig. 1). The students had to elaborate geochemical maps with the analytical data and the geographical location, in order to identify the main areas affected by the pollutants under study.

The study has at core the following methods of collecting information: traditional method (by using logical responses given by students in the implementation of focus group technique), rational method (using questionnaires with objective items), mystical way (by using responses given by students based on irrational, mystical, augmentation and moral portraits of famous teachers), intuition way (by using first impressions that students have formed about the teacher) and empirical way (based on observation of reality and analysis of students’ degree of involvement in course and seminar activities).

In order to evaluate the efficiency of the methods, we used the rational method (questionnaires), combined with personal interviews as well as observation of the degree of involvement by the students (measured by the number of tutorial sessions and tutorial e-mails). The level of satisfaction in the questionnaire ranged from 0 to 10, evaluating the parameters methodology, field survey, laboratory methodology learning and general satisfaction. The average mark obtained was compared with the historical records for the module.
3 RESULTS

3.1 Design thinking approach

There were three different methods used by the students. Several students preferred collecting the samples systematically through a regular grid survey. Another group preferred sampling along radial transects located at random angles. Finally, a third group opted for a random survey.

After the presentations of the proposals, all students and the professors decided to produce a radial sampling campaign based on transects, each being 45°, each transect consisting of sampling points separated 250 m (Fig. 3). The total examined area finally covered a circular surface of 1 km radius taken from the centre of the old mining facilities.
During the interpretation of the results, the students revealed that the arsenic affection was higher at the center of the sampling grid with concentrations decreasing at growing distances from the central point of the mine.

### 3.2 Evaluation of the design thinking methodology implementation

The average score obtained for each part of the complete work is shown on a scale from 1 to 10 in Table 1. The results were excellent and better than the expected. The students evaluated the field activities with the higher score. However, the satisfaction level with the laboratory equipment obtained a mark of 9.2. The methodology was evaluated with a 9. In this case, students faced difficulties during the methodology stage because of the complexity of GIS software. This tool was explained during the course of the module. However, the time the students could devote to developing these skills was not enough for them to be satisfied.

<table>
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<tr>
<th>Table 1 Students satisfaction survey scores (scale 1 to 10).</th>
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<tbody>
<tr>
<td><strong>Average score</strong></td>
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<tr>
<td>Methodology</td>
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<td>Field survey</td>
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<td>Laboratory</td>
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<td>Activity (global score)</td>
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The average final mark obtained by the students in the module was 8.5 out of 10, while the average mark obtained by last year’s students, when DT had not yet been implemented, was 5.7 out of 10. The increase in the mark obtained by the students could probably due to the methodology applied. The number of e-mails received by the professor before DT was 5, and increased to 40 after it was implemented. Similarly, the number of personal tutorial sessions increased from 4 personal tutorials to 10 group tutorials. The learning satisfaction was also assessed by directly asking the students on their level of satisfaction with the newly implemented methodology throughout the course. The overall impression arrives at a similar conclusion for the personal questionnaires and ratifies the better communication between student and professor.

### 4 CONCLUSIONS

The personal interviews, the increase in the number of tutorials and e-mails as well as the personal questionnaires confirm an increase in the number of students for the module after implementing DT. These ideas are confirmed by personal interviews to the students who failed to pass the previous year. Personal interview given to these students confirmed these assertions.

With regard to the learning outcomes, the DT methodology revealed a useful approach to improve the technical and conceptual skills of the students as indicated by the quality of the work they produced. With regard to transversal skills, the carrying out of a real engineering case study resulted in a better connection between concepts, more empathy, system thinking and creativity. These impressions were general in the professors during the class sessions.

The main concern with DT comes from the difficulty to ensure that all students cover the entire syllabus of the module. This way personalized tracking of the work produced by each student was crucial. The creation of homogenous groups was also particularly challenging for us.

Overall, the DT method proved successful for the modules related to the environmental & mining engineering field. This successful experience has encouraged us to apply this method to more Mining Engineering Degree Modules, namely Minerals Exploration and Advances Mining Methods.

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