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BRIDGE DESIGN MASSIVE OPEN ONLINE COURSE

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Abstract. In last years, the traditional blackboard teaching has been incrementally supplemented by visual aids like slide projectors and videos. The phenomenal growth of the internet has brought in new teaching media, such as Massive Online Open Courses (MOOCs) that open the educational experience up to a broader and more distant set of students. This easy access to education can increase motivation and it is a useful commercial tool for universities. Unlike other disciplines (such as economics or psychology), the MOOCs are rarely used to spread civil engineering courses. To fill this gap, and to encourage the use of MOOCs among civil engineering schools, this paper presents the experience of the MOOC for the multidisciplinary design of bridges created by the University of Castilla-La Mancha (Spain). This MOOC is an ambitious project of the civil engineering school of Ciudad Real that includes the collaboration of most of its fields (structural engineering, transportation, urban planning, geotechnical engineering, material science, project management, environment engineering, topography and hydraulic engineering).

1 INTRODUCTION

Throughout history, traditional teaching, in which a professor led the learning experience of the students with nothing but a blackboard, has been the most common educational methodology. Despite traditional learning has been quite straight forward, some variations have appeared in the last years. For example, since the 90s, some practical disciplines (such as medicine or engineering), complement traditional teaching with the Project Based Learning (PBL). In this methodology, the students are the ones leading the classes by using their recently acquired knowledge to solve proposed problems under the professors' guidance, and through self-directed reflection, research and practice in solving them [1]. The popularity of PBL is an example that illustrates the advantages of adapting the educational methodologies to the different contents to be taught.

A major change in education history started with the computer revolution, as new and emerging pedagogies brought dramatic changes in the educational landscape. Since then, the phenomenal growth of the Internet has increased the popularity of computer based educational

tools, such as E-learning, which enable the students to learn anywhere and anytime. The endless possibilities of these new tools include the ability to share material in all kinds of formats, conducting live online classes (webinars), as well as enabling communications with professors and other students via chat and message forums. International associations (such as IABSE [2]) use E-learning platforms to spread Civil Engineering worldwide.

In this way and with these tools, it is intended to bring science and technology, and more specifically the design and structural functioning principles of bridges and buildings, closer to public outside the university, motivating participants to discover them in a pleasant and intuitive way. Two activities have been planned to be developed, based on the PBL methodology, and using mostly K'nex toy pieces (see Figure 1): (1) Bridges design contest for pre-university students from all over Castilla-La Mancha. (2) Building structures design competition, which will be launched during this year. In this contest, pre-university and university teenagers from the UCLM (Ciudad Real and Cuenca) and CEU San Pablo (Madrid), will design and build a structure in a seismic zone.

Figure 1: Pieces of K'nex construction system.

During the last years, in the first case, as a complement to the preparatory phase of the contest, we have conducted face-to-face classes, limited in time and with an eminently practical approach aimed to build the bridge. As a novelty this year the Massive Open Online Course (MOOC) presented in this paper, has been developed, to allow a much more complete, multidisciplinary and accessible knowledge about bridges to every participant.

2 PROJECT BASED LEARNING AND CONTESTS

Students demand an education that helps them to acquire the skills required by their employers, easing their early recruitment in construction companies. Aware of this necessity Aalborg University in Denmark incorporated the Project Based Learning (PBL) in its academic

program in the 70s. The Civil Engineering School of UCLM was the first one in Spain adapting PBL in its studies. Nowadays, both the Degree and Master on Civil Engineering offered by this School include a number of PBL subjects focused on each of the major professional areas (Structures, Hydraulics, Transportation and Urban Planning). A major concern of all these PBL subjects refers to those concepts already acquired in preceding teacher driven subjects [3].

On the other hand, The Civil Engineering and the Building Engineering schools have also incorporated the participation in national and international contests as part of their motivation strategies to encourage students.

As an example of implementation of this methodology also out of the schools, the following sections describes the contests of bridge construction with K'nex and building construction for high school students.

2.1 Contest on bridge construction with K'nex

The aim of the contest is to enable high school students of Castilla-La Mancha Region (Spain) to understand the number of disciplines involved in the design of bridges by building a scaled bridge in a certain location based on structural, economic, construction, environmental and aesthetic considerations. To do so, the students were provided with the construction toy system K'nex.

The contest was founded on his Third edition by the Spanish Foundation for Science and Technology (FECYT), UCLM, the company ProiMancha and Spanish Professional Association of Civil Engineering (Colegio de Ingenieros de Caminos, Canales y Puertos).

The contest is divided into two different stages [4]:

- Stage 1: Free bridge construction. The teams were divided into semifinals, where they were challenged to build in 1 month a bridge supported on two boxes (Figure 2). The participants fixed all design parameters based on the following sections: (1) Cost (20%). Each K'nex piece was assigned with a price in such a way that a symbolic bridge cost could be estimated. (2) Span (30%): The longer the span (and the closer to 180cm) the better. (3) Load (25%): The higher the loading bearing capacity of the bridge (and the closer to 6kg) the better. (4) Valuation of a group of experts (25%).

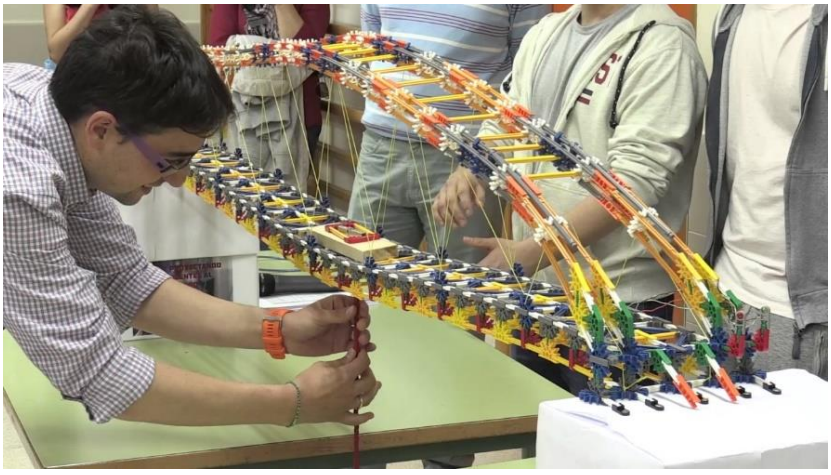

Figure 2: Example of the Semifinal designs.

- Stage 2: Adapting the design for a certain location. The winners of each semifinals were challenged to adapt and built, following actual construction techniques, their initial designs in 6 hours (see Figure 3). All the teams have to use the same scale model (E 1:50) reproducing a section of the Tajo River in Toledo (Spain). In order to ease the excavation of the foundations these models are made of polyethylene (Figure 3). The winner was selected according to the following criteria: (1) Span (10%): All participants spanned 180cm, nevertheless this length might be reduced if intermediate elements (such as piles or pylons were used). (2) Cost (20%), (3) Bridge Depth (20%): The thinner the bridge depth the better. (4) Deflection during a loading case (20%): The smaller the deflection under 2kg load the better. (5) Valuation of a group of experts (20%), (6) Valuation of the public on an online survey (10%).

Figure 3: Suspension bridge design built on the 2017 contest.

All the designs of the Second Stage were included into an exhibition at the train stations of the main cities of the Castilla-La Mancha Region (Toledo, Ciudad Real and Albacete). A picture of the exhibition in Toledo is presented in Figure 4.

Figure 4: Exhibition at the Train Station of Toledo (2017).

As presented in the following section, the built bridges were also used as examples to illustrate multidisciplinary design aspects on the developed MOOC.

3 MOOC AS A MULTIDISCIPLINARY LEARNING TOOL

Due to their unlimited possibilities, one of the most popular Internet learning tools are the Massive Open Online Courses (MOOCs) [5]. In addition to non-traditional course materials such as filmed lectures, problem sets, MOOCs might provide interactive user forums to support learning interactions, homework/assignments, and online quizzes or exams. Unlike other tools, MOOCs are based primarily on short (5-20 min) pre-recorded video lectures, which the student watches on a weekly schedule. Among the most popular MOOCs platforms it is to highlight Coursera [6], and edX [7].

3.1 MOOCs on Structural Engineering

Unlike other disciplines (such as economics or psychology), MOOCs are rarely used in Civil Engineering. To illustrate this conclusion the topics of the MOOCs listed on the main MOOC platforms (Coursera and edX) were analyzed. For example, in the field of "Structural Engineering" the number of MOOCs is significantly low (2 out of 669 in Coursera and 8 out of 1409 in edX). Some of these Structural Engineering MOOCs are listed in Table 1.

Table 1: MOOCs on Structural Engineering

Title	University	Platform
L'art des Structures 1: Cables et arcs. École [8]	École Polytechnique Fédérale de Lausanne	Coursera
Mechanics of Materials I: Fund. of Stress & Strain and Axial Loading [9]	Georgia Institute of Technology	Coursera
The Art of Structural Engineering: Bridges [10]	Princeton University	edX
The Engineering of Structures around us [11]	Dartmouth University	edX
Dynamics [12]	Massachusetts Institute of Technology	edX
Introduction to Steel [13]	Tenaris University	edX
Advanced Introductory Classical Mechanics [14]	Massachusetts Institute of Technology	edX
Mechanics Review [15]	Massachusetts Institute of Technology	edX
Elements of structures [16]	Massachusetts Institute of Technology	edX
Mechanical Behavior of Materials, Part 1: Linear Elastic Behavior [17]	Massachusetts Institute of Technology	edX

The analysis of Table 1 shows that most of MOOCs in "Structural Engineering" are based on very specific technical concepts. In fact, the authors were unable to find more general courses focused on the design of bridges. To fill this gap, and to encourage the use of MOOCs among Civil Engineering Schools, next section presents the experience of the MOOC for the multidisciplinary design of bridges created by the University of Castilla-La Mancha (UCLM).

3.2 MOOCs for bridge design

This MOOC is based on the experiences learned during the three editions (2015, 2016 and 2017) of the bridge construction contest with K'nex for undergraduate students, and it is introduced as a novelty on the running fourth edition (2018). The aim of this contest was double. On the one hand, introducing potential students into one of the most encouraging works of a civil engineer, this is: designing and building a bridge in a certain location including structural, economic, construction, environmental and aesthetic considerations. On the other hand, introducing potential students in the key methodological teaching tool of this school: the PBL, by letting them do instead of telling them what to do.

Different areas from the Civil Engineering and Building Engineering Schools of UCLM participated on the elaboration on a MOOC addressing the considerations of their fields for the multidisciplinary design of bridges.

The developed MOOC [18] is divided into different areas (such as Structural Engineering, Hydraulic Engineering or Geotechnical Engineering). For each of these areas, the students will

have available different recorded lectures. The following lectures were recorded with the help of the C:TED: (1) Fundamental structural concepts: Compression, Tension, Bending, Shear and Torsion. (2) Bridge Typologies: Beam bridge, Truss bridge, Frame bridge, Arch bridge, Cable-Stayed bridge, Stress Ribbon Bridge, and Suspension bridge. (3) Urban Planning. (4) Geotechnical Engineering: Pads, and Piles. (5) Hydraulic Engineering: Laboratory test showing the piles excavation in a stream. (6) Material Engineering: Laboratory tests showing the behaviour of different materials. (7) Construction techniques of each bridge typology. (8) Transportation. (9) Topography. (10) Environmental Engineering. (11) Budget. Examples of some of these lectures are presented in Figure 6. Nowadays the MOOC is only available in Spanish by it will be translated to English in the near future.

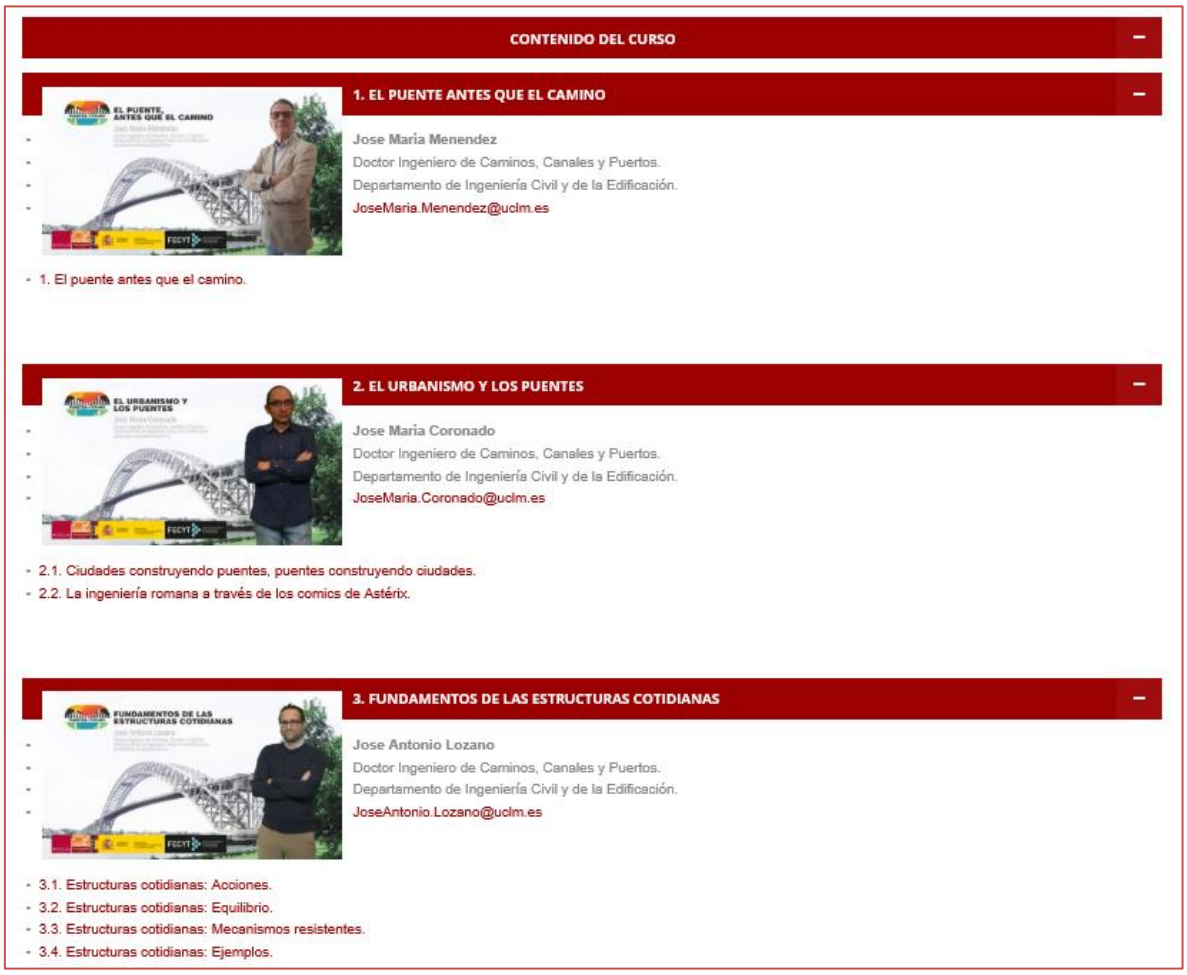

Figure 6. MOOC lectures

Every lecture consists of one to five short videos, from 5 to 15 minutes, exposing the main topics of the area and illustrating with pictures the technical explanations. It has been of special interest the use of virtual models (K'nex connectors and rods have been modeled with blender) to make explanations more enjoyable and easier to understand technical concepts (Figure 7).

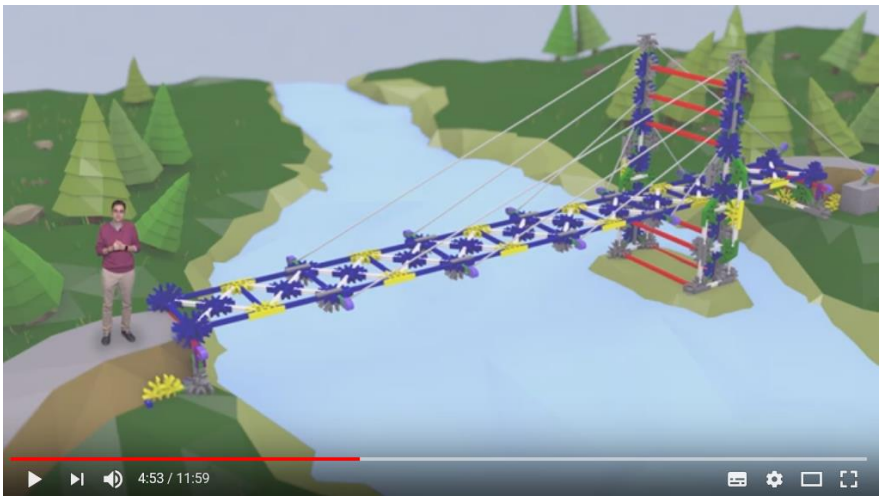

Figure 7. Video frame with a virtual model

After understanding each area, the students will adapt what they learned to the examples of the K'nex bridge. They also have access to open forums where they can discuss directly with the professor in charge as well as with other students. Examples of these activities were answering forum questions or identifying the main structural stresses (compression, tension, shear, bending or torsion) in the different elements of everyday structures (such as the baby cradle presented in Figure 8).

Figure 8. Baby cradle used in the activities of the MOOC to identify its elements behavior

The MOOC will be publish into the most common MOOC platform in Spanish (Miriada X) in the coming months.

4 CONCLUSIONS

This paper presents the first Massive Open Online Course (MOOC) for the multidisciplinary design of bridges based on the experiences learned from the contest on bridge construction with K'nex for undergraduate students organized by the Civil Engineering School of University of Castilla-La Mancha (UCLM) in 2015, 2016, 2017 and 2018. This MOOC addresses the main issues for the design of bridges from the main civil engineering areas (such as structures, materials, hydraulics, transportation, urbanisms, construction technique or topography). These videos are based on short presentations (5 to15 minutes) including virtual models developed in Blender. In order to strengthen the taught concepts a number of activities are proposed.

The MOOC has been developed in Spanish and it will be publish in the Miriada X platform in the coming months. In the near future it will also be translated to English.

We hope the published MOOC will strength the profession of Civil Engineering as hopefully will encourage young people to study it.

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