Designing a MOOC for a Capstone Project in Civil Engineering

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Abstract: Massive open online courses (MOOCs) provide an alternative method of self-paced learning. Through MOOCs, students can attain the latest knowledge from top educators worldwide. The ability to deal with real case projects is required for the engineering learners in their future career. In addition, a capstone project is designed for learners to integrate the knowledge and skills taught in previous courses, thus training the engineering learners to acquire the skills required for solving real cases. In order to enable more learners to enroll in a capstone project course, we design a capstone course for civil engineering on the MOOC platform. However, some challenges are encountered when a capstone project course is offered on the MOOC platform. In this study, three challenges are discussed. First, improvement of the method of interactions among teacher and students; second, designing an assignment assessment process for numerous learners; and third, using a simpler design for objectively selecting top learners. To address these challenges, some strategies are employed by the authors in the course design of a MOOC for a civil engineering capstone project. The authors expect the measures and outcomes discussed in this paper to benefit other educators who wish to design similar capstone project MOOCs.

Keywords: MOOCs, Online Course, Capstone Project, Project-based Learning, Course Design, Engineering Design, Engineering Education.

Introduction

Massive open online courses (MOOCs) provide online courses that allow unlimited participation through the Internet (Kaplan and Haenlein, 2016), and they help in overcoming space and time restrictions. Learners can learn the latest knowledge from top educators from anywhere in the world. Teachers upload their video lectures, handouts, and other teaching materials online, which can be accessed by learners by themselves without space or time limitations. After finishing a course, the MOOC platform, e.g., Coursera, gives certifications approved by universities (Young, 2013). However, due to the excessive number of learners participating in the course, teachers can barely interact with all of the learners. As the result of developments in the attempt to enhance interactions among the participants, many MOOC platforms provide interactive user forums for learners, teachers, and teaching assistants (Brinton et al., 2016).

The department of Civil Engineering at National Taiwan University (NTUCE) has published seven CAD/BIM (Computer-Aided Design/Building Information Modeling) MOOCs on Coursera since the summer of 2015. The series of courses, named Technology and Application of CAD/BIM, contains four courses about CAD and three about BIM. The first four familiarize beginners with 2D CAD and SketchUp and let learners create basic engineering elements using these techniques. The learners who complete these CAD courses will be able to finish simple modeling assignments with computer techniques, but it is far from enough to be a BIM engineer. Therefore, the last three courses focus on the application of BIM tools. The first course offers an overview of BIM information and basic operation of the modeling tool, Revit. In the second course, the learners need to build a six-floor model and learn the construction process in order to understand the relationship between BIM modeling and construction. The last course teaches BIM applications in the building lifecycle and the practices of two basic BIM applications: quantity takeoff and 4D simulation. These Coursera courses benefit those who want to learn CAD/BIM but face difficulties with respect to time or space. Learners who pass these seven courses are expected to finish capstone projects (Kang and Hsieh, 2015).

Capstone courses make learners integrate, analyze, apply, and deepen what they have learned from their disciplinary and interdisciplinary education. The course sums up students' previous learning and provides them new topics to explore simultaneously. According to the Institute of Engineering Education Taiwan (IEET), there are two main advantages of a capstone course. First, it can provide an overview of the learner's learning outcomes. The learner can check whether he or she has gained the expected knowledge. In addition, since the learners need to accomplish an entire project by themselves, it will serve as an

experience required for handling actual scenarios. Second, teachers can determine the learning conditions of learners and improve the curriculum design based on the performances of leaners in the capstone class. Furthermore, capstone courses in the engineering education field are proved to be able to increase the interests of learners and enhance the teaching effects (Terrón-López et al., 2016).

In recent years, NTU has been devoted to implementing capstone projects in classes. For example, NTUCE offered a capstone course divided into two teams: Xitou Forest, for the design of a cableway system, and Wushe Reservoir, for the design of sedimentation countermeasures, as an elective in the first semester of 2010. Although the design process was similar to other capstone courses, the final presentation was limited to written and oral reports instead of material product. In 2012, however, NTUCE provided a rare opportunity for students to put their learning into practical application when it decided to renovate its student space. A capstone course was conducted, and the students who enrolled in it were given the opportunity to build their own activity space, from the design to construction stages (Chiang, Hsieh et al., 2014). This complete design-to-construction project was an invaluable experiment for NTUCE to improve future capstone courses. Due to highly satisfactory learning results from the in-class students, NTUCE decided to make capstone courses an academic requirement in 2013.

According to the positive experiences of the capstone project courses in NTU, we believe that offering the capstone courses on the MOOC platform could provide more people the chance to gain better knowledge about practical works, since participating in practical projects is indispensable in civil engineering. This study introduces a Coursera course designed by NTUCE. The course is a project-based capstone course, containing fewer videos but more implementations. Instead of just giving lecture videos, educators build a realistic environment and provide resources for students. Some challenges encountered when the course team offers a capstone project on the MOOC platform are mainly related to the following: few interactions among teachers and learners, fair assignment assessment through peer review, and selecting top learners in a large amount of learners. This paper discusses these aspects and proposes measures that can be adopted by the designers of online capstone courses.

Design Considerations for a Capstone Project

A capstone project course aims to enable learners to integrate techniques and information that they learned from the previous seven courses, use them skillfully to finish a real project by themselves, and be competitive members in the CAD/BIM field. To achieve these goals, this capstone project must be designed delicately to ensure that the majority knowledge of CAD/BIM is included.

Basically, a capstone project course can be divided into two types in terms of the number of people included in the project: team-based and individual. In an individual project course, each learner completes the project individually; therefore, they can go through the whole process of the project by checking the learning result and developing various kinds of professional skills. On the other hand, in a team-based project course, the work is divided among the team members, and so each learner is responsible for just a part of a project. As a result, the learner realizes only the part he or she engages in, without checking other parts of the project. The course we introduced at NTUCE is an individual capstone project to fulfill the aforementioned goals. First, this integrated curriculum mainly reviews the entire courses the learners have attended and confirms that they have attained all the required skills and knowledge. Second, one of the most important features of MOOCs is that the learners can learn at their own individual paces. Every learner has his or her own learning schedule. In contrast, in a team-based course, the team members must inevitably advance at the same pace, requiring fast learners to slow down or causing stress to learners who need more time to complete the lessons on time.

Challenges in Designing a Capstone Project

Many challenges are faced while designing a capstone project, which can be divided into three aspects: limited interactions among teachers and learners, assignment assessment, and selecting top learners. Each aspect will be thoroughly discussed in the following section.

Limited interactions among teachers and learners on MOOCs

Interaction is the most important factor deciding the success of a capstone project. This is because various problems are often encountered during the course of a project, and these can be tackled only when teachers and learners interact and solve them together, thus running the project successfully.

In addition, since the major feature of a capstone project is that it is project-based, while conducting a capstone project on the MOOC platform, this feature cannot be expressed easily. Capstone projects are mostly run in a classroom, and so they allow teachers to check learners' progress face-to-face, making the teacher's role similar to that of a project manager checking the progress during a project. However, a capstone project run on a MOOC platform lacks in interaction scenarios that can give the learners the feel of a real project.

Assessment of Assignments

Giving assignments is an essential method for teachers to assure the progress of learners. In conventional classroom learning, the teacher delivers assignments to the learners based on the lecture content in the class. Learners submit their assignments on the due day set by the teacher in the class. The teacher then reviews the submitted assignments of every learner and gives them feedback in the subsequent lecture time.

A capstone project on the MOOC platform adopts another method for assignment delivery. Because the learning schedules of learners differ, the assignment is announced on the MOOC platform after learners finish each lecture. Since the MOOC platform allows numerous learners to take the courses, it is impossible for the teachers to review every learner's assignments. Therefore, a peer review system is adopted for the teacher to deal with the assignments, in which every learner reviews another learner's assignment.

However, designing the peer review system is a challenge. The evaluation of the learners may be subjective and they might follow different standards for peer reviews. Therefore, the criteria of the assignments must be easy and objective so that learners review other learners' assignments in a more objective and consistent way.

Selecting Top Learners

The assessment process is also important for a capstone project. In order to find the top learners, an assessment process must be comprehensible. In capstone project courses conducted in classrooms, an exhibition is held at the end of the course, where every learner demonstrates his/her project work to the judges. The judges review all the learners' works and give them a score. The learner who receives the highest score will be the top learner. However, a capstone project conducted on the MOOC platform is different as a huge number of learners participate in the course. Arranging an exhibition for demonstration would encounter time and location constraints; therefore, running an exhibition on the MOOC platform is impossible. An alternative method to select top learners on the basis of the highest scores on the assignments. However, the criteria of assignments were easy and objective to facilitate objective peer review. Therefore, the fact that the learner who has the highest score in the assignments is the top learner cannot be guaranteed. They may be considered to have just passed the basic standard of this course. In short, only using the assignment scores to find the top learners is questionable. A final project report in the format of a portfolio is needed.

Course Design and Implementation

To address the aforementioned challenges, this section discusses the measures taken in the course development period and demonstrates the outcomes. We will introduce and analyze several designs in this chapter, including course contents, assignments, the assessment system for assignments, portfolio design, and the portfolio assessment process and criteria.

Role Play as a Teacher and a Project Manager

Course contents are aimed at letting learners get the experience of a real project and so are designed as role-plays. That is, the teacher would not only be a teacher but also play the role of a project manager, so as to engage in more real projects. As shown in Figure 1, learners can clearly distinguish the character of a teacher and a manager by background, dressing, and mood. As a result, learners can simultaneously feel the care of the teacher and complete the projects assigned by the manager.

This project is designed as five stages: modeling, cost estimation, 4D simulation, and two design changes. In the first three stages, learners experience a preliminary project and using BIM tools finish the tasks in each stage. Three types of BIM software that are commonly used in industry were chosen in this course: Revit® is used to build the whole model and estimate the cost of a project; SketchUp® is used to build surrounding buildings; Navisworks® is used to simulate the process of construction. All the above software has been introduced in previous courses; thus, the learners have a chance to review them and know how to implement the techniques into a real project. After learners finish the preliminary project, they experience two design changes; they would be notified by the project manager to perform a design change that happens commonly in the civil engineering field. Learners can thus experience a real project similar to that in the industry.

(a) (b)

Figure 1. The teacher plays two roles: (a) a professor and (b) a project manager of the project.

Image-based Submission and Objective Peer Reviews

The assignments in MOOCs are designed as peer review assignments that are assessed by learners. The assessment standards of assignments may depend on the subjective and non-uniform judgment of learners. Therefore, the course assignments are designed to be

small and non-controversial for evaluation. A week's progress is divided into many small milestones. Each milestone is developed to a peer review assignment. As the assignments are small, the criteria, which are simple and clear to follow, can be delicately listed. We designed a series of criteria for each assignment to ensure that the level of learners' performance has reached the specific basic standard.

All of the peer review assignments are submitted in image formats. The learners are required to submit their assignments as several screenshots, which should comply with the criteria specified by the course team. A modeling assignment example is shown in Table 1, which contains the screenshots and the criteria. The week's progress is divided into four milestones: build roofs, stairs, and tilted walls, and decorations. Because the assignments are small and mainly focus on one goal, details for the milestones can be written clearly and the criteria can be listed. As shown in Table 1, two screenshots for the decorations are shown in the assignment. By referring to the screenshots of the model and the description of the assignment, learners are more likely to finish the jobs as expected by the teacher. Once the learners finish their assignment, they are asked to review the assignments of others.

The assessment system for assignments is designed for learners to peer review very equitably. The grading standards play an important role; the true/false questions were set for learners' peer reviewing. A question must be very objective, allowing the learner to answer whether the picture matches with the target image of the assignment. Table 2 shows an example of peer review questions. The questions contain definite answers according to the designated pictures; as a result, the grading standard would be uniform. Furthermore, in order to ensure that the assignments receive accurate grades, an assignment is graded by at least five learners.

Portfolio for Selecting Top Learners

The criteria for the assignments are objective and easy to follow due to the peer review process. Learners who get high scores in their assignments are considered only to have definitely passed the basic standards of the course. In order to select the top learners, a strategy for advanced assessment is needed. In this section, a portfolio is designed for learners to express all of the skills they have learned. Besides, an evaluation process is formed to select the top learners based on the portfolios.

In the portfolio report, learners are required to organize their weekly completed works and then extend their works to make the portfolio. The suggestions of extended works are listed in each assignments. Learners can choose the extended topics based on their own interests. In addition, various submission formats are allowed for the portfolio, including keynotes, documents, posters, or videos. The freedom of creating a portfolio encourages learners to showcase what they have learned in the capstone project. Teachers can then select the top learners by evaluating the portfolios.

Table 1. Criteria and screenshots of decorations in the peer review assignment

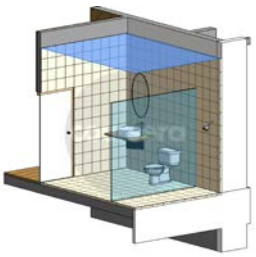
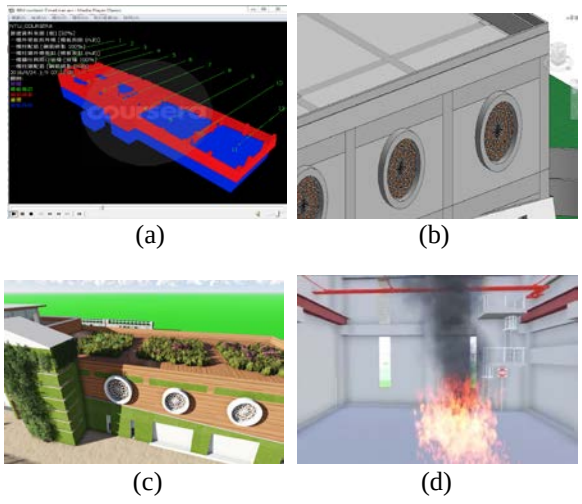
Screenshots	
	
(a) The lounge at 1st floor	(b) The restroom in 1st-floor lounge
Criteria	
According to the example, please follow the steps to create screenshots (a) Use Section Box to crop the model as the same angle of view of Figure (a). 1. Hide the Section Box and take a screenshot. 2. Name the image as 01. (b) Use Section Box to crop the model as the restroom in the 1F lounge with the same angle of view of Figure (b). 1. Hide the Section Box, select the roof element, and take screenshots. 2. Name the image as 02. Create a .zip file of the two images and submit it.	

Table 2. Screenshots and peer review questions of design change

Assignment picture	True/false questions
	• Is the height of B1 floor 3200 mm? • Is the B2 floor 3600 mm? • Is the excavation depth 8800 mm?

At the end of this course, every learner will be required to submit a portfolio as a final report of this course. The portfolio may contain details of not only this capstone project but also the extended research.

Figure 2 shows an example of the content of a portfolio, which are 4D simulation, component design, 3D display, and fire simulation; that is, any kind of content about this project is acceptable in the portfolio. In order to lead learners while doing the portfolios, the course team designed several extended suggestions at the end of each week. In addition, the portfolio can be submitted in various formats, including slides, reports, posters, and videos. Learners are given the freedom to collate and organize their works in their own way.



(a) (b) (c) (d)

Figure 2. Example of portfolio contents: (a) 4D simulation, (b) component design, (c) 3D display, and (d) fire simulation.

The teachers assess the portfolios following a process and identify the top learners. The assessment system of the portfolio is divided into five indices: completeness, practicality, use of advanced technology, format consistency, and innovation. One to three multiple choice questions are set against each index, so as to evaluate the grade in a uniform way. The indices and their corresponding criteria are shown in Table 3. Furthermore, the assessment process is divided into three stages: portfolio peer review, review by course assistants, and review by professional engineers. The first stage is the initial assessment of each portfolio by five peer learners, which gives an initial average grade. Then, all the learners' portfolios are ranked for the first time, and the top thirty percent will enter the second stage. In the second stage, a review grade is given by course assistants. Course assistants will grade with discussion and keep the standard the same, and they will examine the peer review grade to check whether it is reasonable and fair. Subsequently, the portfolios are ranked again according to the average grade, and the top ten percent will be sent to the last stage, where professionals select the top learners.

Table 3. Criteria for the portfolio peer review

Index	Criteria
Completeness	Check whether the portfolio contains the extended part of each assignment.
Practicality	Check whether the extended project outcomes can be used in real cases by • owner • designer • constructor • operator
Advanced technology	Check whether the learner used additional technology such as • modeling software • analysis software • management software • application developing
Format consistency	• Check the consistency of the portfolio forms, such as the word size and fonts. • Check whether colors in the portfolio are used with clear purposes. • Check whether the picture or photos in the portfolio is clear.
Innovation	Check whether the portfolio contains new issues not mentioned in the course.

Conclusions

MOOCs have been transforming education by changing the method of delivering lessons, from traditional in-class courses to widely open online courses. Benefits brought by MOOCs have enabled more people to acquire knowledge without limitations of time or inconvenience of distance, as they increase the flexibility of scheduling self-paced learning plans. Capstone projects are important practice for civil engineering education aiming at guiding and facilitating learners to integrate knowledge learned from previous lessons; utilizing the advantages of MOOCs in developing a capstone project provides better design probability and diversity for its course content. However, there are some challenges that need to be tackled in the design of a capstone project course on the MOOC platform. The challenges mainly arise due to the difference in the scenarios of running a capstone project on an open course website and that in a specific teaching space. Three challenges were discussed in this paper, i.e., how to enhance interactions among learners and teachers, how to design the assignments, how to determine the top learners from the huge number of learners. The strategies adopted and the methods designed in this research help overcome these challenges and thus achieve an online capstone project course that

successfully teaches the BIM concepts and technology in the civil engineering field.

In summary, a capstone project course based on the MOOC platform enables learners from anywhere in the world to join in one course and integrate their knowledge and skills, thus enhancing their proficiency and inspiring their inherent potential. In order to achieve these goals, the issues encountered with a capstone project and MOOCs must be well addressed by designing the course's structure, content, and operation process. In this paper, we discussed the important aspects dealing with the challenges. By sharing the experience of designing a capstone project course offered on the Coursera platform, we hope that the design process and methods described in this paper contribute beneficial information for designing similar types of courses.

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