

Improving Construction Digitalization Literacy through the Development of Building Information Modelling Learning Contents Based on Massive Open Online Courses (MOOCs)

M. Mirza Abdillah Pratama*, Julieta Eka Yudo Putri, Cynthia Permata Dewi, Vita Ayu Kusuma Dewi, and Muhammad Aris Ichwanto

Department of Civil Engineering and Planning, Faculty of Engineering, Universitas Negeri Malang, Indonesia

**Email: mirza.abdillah.ft@um.ac.id*

ABSTRACT

The influence of technology on education and the Open Access movement also supports educational institutions to develop Massive Open Online Courses (MOOCs). MOOCs is an online course facility platform that can be accessed openly and free of charge by the public to improve the competencies of interest. In the field of architectural, engineering and construction or facility management (AEC/FM), mastery of Building Information Modelling (BIM) is a necessity for society and industry, as well as to equip themselves in the face of rapid digitalization of construction and technological disruption. BIM can improve project quality management, both in terms of controlling time, cost, and quality of work. However, the implementation of BIM faces obstacles, especially about resources, due to the limited availability of free BIM course platforms. Through this program, a content development program is proposed at MOOCs related to Building Information Modelling that can be followed by the general public, practitioners, and academics. The contents were developed with the ADDIE development model. The content developed includes learning design, handouts, presentation slides, video explainers, audio, and assessment tools. The results show that the MOOC content developed is easily accessible to students and can improve mastery of digital technology in the construction field.

Keywords: *Massive Open Online Courses (MOOCs), Building Information Modelling (BIM), digital technology, construction.*

1. INTRODUCTION

1.1. Background

Construction is classified as a sector with low productivity figures when compared to automotive [1], [2]. The integration of technology in construction so far is a technology that has developed in the past 20-30 years. In fact, construction is an industrial sector that involves intensive information and communication at every stage, including design, implementation, use, maintenance, and demolition [3]. With the increasingly complex scope of work, the application of traditional technology is a threat that has an impact on decreasing the quality of work.

Building Information Modelling (BIM) is a method that integrates technology in a project involving the architectural, engineering and construction or facility management (AEC/FM) sector to create good communication and collaboration between stakeholders [4], [5]. In its implementation, BIM can improve project quality management, both in terms of controlling time, cost, and quality of work. In terms of time, BIM can assist

job owners in making decisions quickly, assist in detecting potential clashes during the design stage, minimize project execution time, and avoid opportunities for lost data [6], [7]. In terms of cost, BIM integration can avoid cost overruns caused by rework or revision. In terms of quality, the use of BIM can help stakeholders to communicate and collaborate effectively and avoid miscommunication. On the other hand, BIM can assist K3 officers in predicting possible hazards during project implementation and assist in designing safety plans to prevent work accidents [8].

BIM can be used to obtain information up to 7 dimensions [9], [10], where hierarchically: a) 3D: dimensions of the object, including length, width, and height; b) 4D: 3D information coupled with scheduling; c) 5D: 4D information coupled with estimated costs; d) 6D: 5D information coupled with site location information obtained through the integration of geographic information systems; e) 7D: 6D information coupled with facility management in the project life cycle

Inhibiting factors and challenges in BIM implementation include aspects of resources, processes,

and technology. In terms of resources, construction actors are reluctant to use BIM because they are accustomed to conventional construction implementation, lack of knowledge and competence related to BIM, and lack of vigilance about the benefits of BIM [11]. In terms of process, the government has not provided standard instructions for the implementation of BIM in the construction world. In terms of technology, BIM integration requires a high investment. It is necessary to prepare skilled hardware, software, and resources [12]. Increasing the use of BIM can be done by participating in training and seminars, government policies in the integration of BIM in each project, and cooperation between practitioners, academics, and researchers to conduct education related to knowledge and skills in BIM to undergraduate and postgraduate students. This can be achieved by integrating BIM in the learning curriculum and / or organizing courses on Massive Open Online Courses (MOOCs). This program aims to equip academics, practitioners, and the public regarding BIM knowledge and skills which are mandatory competencies for every individual who is involved in the construction field today and in the future.

Graduates of the field of civil engineering must internalize the scientific core consisting of 4 elements, namely scientific fundamentals, construction materials, construction-applied resources, and field construction operations [13], which is then summarized in the document The Civil Engineering Body of Knowledge for the 21st Century (CEBOK) [14]. In the document, civil engineering graduates must be skilled in the use of technology and use visual and graphic means in communicating within a professional sphere [15]. BIM learning finds challenges, namely: adaptation to the use of software that requires a long-term commitment to be familiar with the user-interface of the program, misinterpretation in the BIM process, and limitations in learning infrastructure. What's more, the modelling process is complex and requires field experience [16]. However, the main challenge in BIM learning is the lack of training by educational institutions. Most of the training is organized by training institutions and paid is expensive. In previous related studies [17], BIM learning is designed to be student-centred and process-oriented by involving teaching activities (lectures), lab-based tutorials, group-based assignments, and independent learning through studying modules. The basic BIM module consists of: (1) cost estimation, (2) 4D scheduling and modelling, (3) design coordination. Additional modules include: (4) energy building simulation, (5) photogrammetric of 3D modeling, and (6) site layout planning.

1.2 Massive Open Online Courses

The development of internet-based technology has shifted the offline learning mode towards online. One of the current trends is MOOCs. MOOC is an online course facility platform that can be accessed openly by the public to improve competencies or skills of interest. MOOCs have been designed to accommodate many participants so that they can overshadow learning in large groups [18]. Similar to ordinary lectures, participants are required to listen to the information presented; read the supporting materials provided; and work on tasks that must be submitted at a predetermined time. The characteristics of MOOCs [19] are a) Massive. MOOCs have the principle of infinite scalability, meaning that the scale is unlimited.; b) Open. There are no special requirements to follow MOOCs; c) Online. Platform must be accessed via the internet; d) Courses. The course program is managed and packaged as one whole learning. There is a teaching plan that contains learning objectives, activities for each meeting, assessments and learning resources. The program also requires students to have suggested learning resources, listen to exposure from the teacher, and take quizzes and do assigned assignments. Participants are also encouraged to engage in online discussions within the forum provided. Participants can also get a certificate if they have completed the lecture.

2. METHOD

2.1 Stages of program implementation

The content of MOOC Building Information Modeling is developed with the ADDIE development model, which consists of the following stages: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. The ADDIE [20] development model is shown in Figure 1.

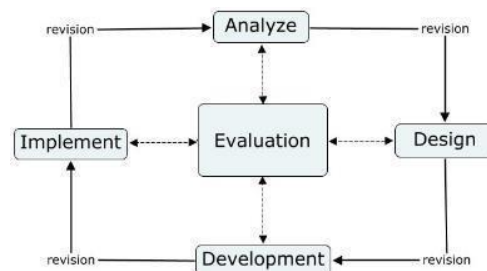


Figure 1 ADDIE development model

2.2 Analysis

The analysis consists of an analysis of program planning needs and an analysis of the results of program implementation. The needs analysis begins with a literature study of relevant research that has been carried out previously, setting post-program achievement

targets, and identifying gaps that occur. The results of further needs analysis are written in Table 1.

Table 1. Needs analysis

Indicator(s)	Requirement(s)
Competence	Participants can understand the urgency of BIM competence in the era of construction digitization and are skilled in the use of BIM-based computer applications
User profile	The public, practitioners, and students of civil, architecture, machinery, and general engineering
User's characteristics	Utilize BIM-based software to model, schedule, and estimate the cost of simple construction work
Expected learning media	MOOC content developed based on a simple and easy-to-understand learning plan, and equipped with learning media in the form of text (handouts) and audio-visual media so that participants can learn the course easily

2.3 Design

Designing consists of preparing a lesson plan of the course to be developed while containing learning objectives, determining the type of content and content design, determining the schedule of development activities, content design and storyboarding, and media testing.

2.4 Development

The development stage contains improvements to content and learning media based on the results of expert and user validation. In this case, the development can be both substance and visual design.

2.5 Implementation

The developer prepares the learning environment and conducts formative evaluations to obtain a record of the content and presentations developed. Formative evaluation can be carried out from small group trials or field trials [22]. Trials were conducted to obtain data for the purpose of determining the level of feasibility, efficiency, and attractiveness of the MOOC content that had gone through the validation stage. The trial at the implementation stage is focused on revising and perfecting the learning media developed. The indicators assessed are accuracy, ease of use, and learning activities.

3. RESULTS AND DISCUSSION

3.1 MOOC Contents

The content developed consists of a lesson plan, handouts in the form of PDFs, presentation materials, explanatory videos, motion graphics, infographics,

podcast audio, and assessment question packages. More on the content of the MOOC content, can be seen in Table 2.

Table 2. MOOC Building Information Modelling Content

Indicator(s)	Detail(s)
Learning plan	<ul style="list-style-type: none"> • timeline, • content description, • participant learning experience, • activities, • learning media, assessments, and reference
Handout	<ul style="list-style-type: none"> • Introduction to Building Information Modeling, • Installation guidelines: Tekla Structures; • Introduction to menu and features in Tekla Structures; • Structural modeling; • Detailing; • Project scheduling; • Clash detection; and • Drawing & Reporting
Presentation slides	<ul style="list-style-type: none"> • Introduction to Building Information Modeling, • Installation guidelines: Tekla Structures; • Introduction to menu and features in Tekla Structures; • Structural modeling; • Detailing; • Project scheduling; • Clash detection; and • Drawing & Reporting
Video tutorial	<ul style="list-style-type: none"> • Basic modeling tutorial; • Assigning connection detail tutorial; • Clash detection tutorial; and • Drawing and reporting tutorial
Audio podcast	<ul style="list-style-type: none"> • Digitization of construction; • Collaboration in construction projects; • The role of BIM in accelerating development; and • Compulsory Skills for the Industrial Revolution 5.0
Assessment tools	Final test

3.1.1 Learning plan

The BIM courses are designed to be completed in 8 (eight) weeks, and can be accessed via <https://mooc.um.ac.id/course/view.php?id=219> using enrolment key: BIM2023. The learning plan consists of a timeline, content description, participant learning experience, activities, learning media, assessments, and references. In general, the learning outcomes expected of students are able: to understand the basic concepts of building information modeling; to install Tekla Structures program (Student version); to operate menu buttons on Tekla Structures; to model building structures

using Tekla Structures; to provide detailing on elements and models that have been formed; to compile job scheduling; to detect the presence of clash and provide resolution; and compiling working drawings and reporting.

3.1.2 Handout

Building Information Modeling handouts were made as many as 8 pieces with 8 different titles, including: introduction to Building Information Modeling, program installation instructions: Tekla Structures (Student version), introduction to menu features on Tekla Structures, structural modeling, detailing, project scheduling, clash detection, and drawing & reporting. The handouts were converted to PDF extensions and uploaded to MOOC UM.

The "Introduction to Building Information Modeling" handout contains general exposure to BIM. The discussions in the module are arranged sequentially so that users can understand BIM easily. The module presentation is complemented by an explanation of the history of BIM, which is derived from the emergence of the BIM concept in the 1970s, followed by the emergence of the term BIM and a brief review of the first BIM software, namely ArchiCAD. In the benefits section, the benefits of using BIM are presented at the pre-construction, design, construction and fabrication stages. In this section, challenges in BIM development are also presented which include 3 aspects, namely People, Processes, Policy. Furthermore, an explanation of the disadvantages and advantages of using BIM was also presented.

Handout "BIM based program installation instructions: Tekla Structures (Student version)" contains explanations and procedures for installing Tekla Structures Student Version. Before explaining the installation tutorial, a brief review of Tekla Structures itself is presented. The version of Tekla described in the handout is Tekla Structures 2021 Service Pack 8. The selection of software version is based on the capacity of the device owned. The installation procedure starts from registering a Trimble account (Trimble ID), followed by license activation. After successful license activation, proceed with starting the application download. The next step is the installation of the application. Exposure to the installation procedure starts from the beginning until the application is ready for use. At each stage, images are also presented to make it easier for users to understand the procedures described.

The handout "Introduction to menu features in Tekla Structures" contains an explanation of the functions of each feature owned by Tekla Structures. At the beginning of the handout, we explained the Tekla

Structures application starting from its general definition and workflow. In Chapter 2, it is explained about the procedure for opening applications and creating new worksheets equipped with explanations of each available menu. Chapter 3 is an explanation of the definition and function of each menu in Tekla starting from the Steel menu which includes column, beam, plate, bolt, weld, item, bolted parts, and assembly. Second, the Concrete menu includes columns, beams, panels, slabs, footing, items, and cast units. Next is the Rebar, Edit, View, Drawing & Reports, Analysis & Design, Trimble Connect, Bridges and Formwork menus.

The "Structural Modeling" handout contains steps for modeling structures in Tekla Structures. The modeled building is a simple 2-story building. The first part of the handout explains how to create a new worksheet in Tekla Structures. Chapter 2 contains steps to adjust the grid line to the model followed by an explanation of the steps for modeling the palm foundation in Chapter 3. Chapter 4 contains an explanation of the steps of pedestal column modeling and Chapter 5 is about the explanation of the steps of tie beam modeling. The steps described basically have the same principle, starting from the selection of features used, modeling on the grid and continuing with detailed adjustments. Chapter 7 contains beam modeling procedures, Chapter 8 contains floor plate and roof plate modeling procedures, and finally Chapter 9 contains ladder modeling procedures. At the end of the handout, a 2D and 3D view of the model is displayed from several grids and different elevations to give users an experience of how the model looks after it has been created.

The "Detailing" handout contains steps to provide reinforcement details on a pre-built model. References for detailing are SNI 2847:2019 concerning structural concrete requirements for buildings and explanations (ACI 318M-14 and ACI 318RM-14, MOD) and Regulation of the Minister of Public Works Number: 30/PRT / M / 2006 concerning "Technical Guidelines for Facilities and Accessibility in Buildings and the Environment". There are 2 methods to provide reinforcement details to structural components, namely manually using the Rebar menu or automatically using macros provided by Tekla Structures. In Chapter 2, the procedure for giving reinforcement to the palm foundation is described. At the beginning of the defecation, it was also explained about the applicable regulations, namely the thickness of concrete blankets. The explanation continues with the selection of macros used and detailed adjustments. Chapter 3 contains steps to provide details on the pedestal column and the main column using the macro feature in Tekla. Detailing is carried out on beams and sloofs using the manual method, which uses the Rebar feature and is explained in Chapter 4. Chapter 5 contains steps to provide

reinforcement on floor plates and roof plates. Finally, Chapter 6 explains the design standards and procedures for giving reinforcement to stairs.

The "Project Scheduling" handout contains reviews of project scheduling, methods, and project scheduling & visualization using Tekla Structures. The Handout consists of 2 chapters, namely Chapter 1 Introduction and Chapter 2 Scheduling and Visualization. Chapter 1 describes projects which include definition, project resources, project management, project scheduling and project control. Chapter 2 describes the procedure for scheduling and visualizing projects using Tekla Structures, starting from scheduling using the Task feature and project visualization using the Project Status feature.

The "Clash detection" handout contains steps to detect clashes that occur in structural components on the model. At the beginning of the module, an explanation is given about clash detection, benefits, types of clash and the influence of clash detection on the world of construction. Chapter 2 explains the procedure for detecting clashes with the Clash feature on Tekla Structures, the type of clash on Tekla Structures, symbols for checking clashes and how to manage the list of clashes.

The "Drawing & Reporting" handout contains steps to output the created model into 2D and a list of material requirements using Tekla Structures' features. This handout consists of 3 chapters which include the Introduction, the Drawing & Reporting and the Reports. The introduction contains reviews of technical drawings, Bill Of Quantity, and Drawing & Reports features on Tekla Structures. Chapter 2 explains the steps to make General Arrangement (GA) Drawing and Cast Unit Drawing. The steps for making working drawings or 2D outputs from Tekla Structures start from explaining layout settings, plotting images to how to save images into .pdf form. In the last chapter, the procedure for calculating material requirements is explained using 2 different features in Tekla Structures, namely Reports and Organizer.

3.1.3 Presentation slides

Building Information Modeling presentation slides were made with 8 different titles, including: introduction to Building Information Modeling, program installation instructions: Tekla Structures (Student version), introduction to menu features on Tekla Structures, structural modeling, detailing, project scheduling, clash detection, and drawing & reporting. The handouts were converted to PDF extensions and uploaded to MOOC UM.

3.1.4 Video tutorial

Four video tutorials discussing about basic modeling tutorial, assigning connection detail tutorial, clash detection tutorial and drawing and reporting were prepared and uploaded to e: <https://www.youtube.com/mmirzaap>, then mirrored to the MOOC UM. The tutorial video playlist can be accessed via:

https://www.youtube.com/playlist?list=PL32_6IvrmE8ZhxZ5aHNaNdJKMzMdQSY7N.

3.1.5 Audio podcast

Audio podcast is created with title: digitization of construction; collaboration on construction projects; the role of BIM in accelerating development; and skills to deal with Industrial Revolution 5.0. Audio recordings are created in WAV extension and uploaded to a Sound Cloud account (<https://soundcloud.com/m-mirza-abdillah-pratama>), then mirrored to MOOC UM.

3.1.6 Assessment tools

Two types of assessment tools were prepared in this course, namely essays at the end of the module, and multiple choices at the end of the course. In each handout, there are 5 (five) essay questions that can be done by participants independently, to measure the level of understanding of the module studied. The assessment tool is multiple choice, created in Google Form, and the access link is embedded in the MOOC. Course graduation can be achieved when the correct score is at least 85%.

3.2 Validation

3.2.1 Validation of learning and teaching plan

The assessment of the learning plan is carried out on 6 (six) aspects as shown in Table 3. The learning plan developed has met all aspects so that it can be used as a reference in MOOCs. The validation results show that all assessment indicators have met the requirements.

Table 3. Validation of learning and teaching plan

Indicator(s)	Score
• Learning outcomes contain aspects of attitudes, knowledge, and skills	100
• Description of content / material related to learning outcomes	87.5
• The suitability of the learning experience to the learning outcomes	87.5
• Compatibility of learning resources with the material	100
• Suitability of the assessment proposal	100
• Current references	100

3.2.2 Validation of handout

Handout assessment is carried out on 6 (six) aspects as shown in Table 4. The handouts developed have met all aspects so that they can be used as a reference in MOOCs. The results showed that all aspects of the assessment were qualified with minor notes on the appearance of the writing that were less readable. This is because the module uses some screenshot images with resolutions that cannot be increased.

Table 4. Validation of handout

Indicator(s)	Score
• Content in accordance with learning outcomes	100
• Content is presented systematically	100
• Use straightforward and easy-to-understand language	100
• Use an easy-to-read font size	87.5
• Use easy-to-understand illustrations, images, and tables (if applicable)	100
• Using current references	100

3.2.3 Validation of Presentation slides

The assessment of presentation slides is carried out on 6 (six) aspects as shown in Table 5. The presentation slides developed have met all aspects so that they can be used as a reference in MOOCs. The validation results show that Presentation can be used further for learning with minor notes on the use of writing size.

Table 5. Validation of Presentation slides

Indicator(s)	Score
• Content in accordance with learning outcomes	100
• Content is presented systematically	100
• Use straightforward and easy-to-understand language	100
• Use an easy-to-read font size	87.5
• Use easy-to-understand illustrations, images, and tables (if applicable)	100
• Using current reference	100

3.2.4 Validation of video explanation

The assessment of the explanatory video was carried out on 3 (three) aspects as shown in Table 6. The explanation video developed has fulfilled all aspects so that it can be used as a reference in MOOCs. The assessment results on the tutorial video show that the video content can be used further in learning.

Table 6. Validation of video explanation

Indicator(s)	Score
<i>Aspects of media quality</i>	
• The quality of the resulting media	87.5
• The suitability of the images and/or videos displayed with the material presented	100
• Clarity of the images and/or videos displayed	100
• Clarity of use of sound effects and/or music	87.5
• Selection of type, size, color of text	100
• Readability of text on media	100
<i>Aspects of language use</i>	
• Good and correct use of language	100
• Clarity of words and terms used	87.5

3.2.5 Validation of audio podcast

Podcast audio assessment is carried out on 3 (three) aspects as shown in Table 7. The podcast audio developed has fulfilled all aspects so that it can be used as a reference in MOOCs. The results of the assessment show that the audio content of the podcast has met the assessment aspects, especially in the use of language, articulation, and straightforward sentence structure.

Table 7. Validation of audio podcast

Indicator(s)	Score
• Good and correct use of language	100
• Clarity of words and terms used	100
• Presentation of sentences in straightforward and easy-to-understand language	100

3.2.6 Validation of assessment tools

The assessment of the question package is carried out on 7 (seven) aspects as shown in Table 8. The question package developed has fulfilled all aspects so that it can be used as a reference in MOOCs. Based on the assessment results, the assessment tool can be used to assess the learning completion of MOOC participants. The 40-point questions have been arranged from easy to difficult difficulty so that participants can get used to thinking critically in solving the questions provided.

Table 8. Validation of assessment tools

Indicator(s)	Score
• The suitability of the question with the learning outcomes	100
• Clarity of instructions for working on the question	100
• Clarity of intent on the matter	100
• The possibility of the problem can be solved	87.5

• The suitability of the language used in the question with the rules of Indonesian	100
• Question sentences do not contain double meanings	100
• Formulation of communicative question sentences, using simple language for participants to learn, easy to understand, and using familiar language	100
• The suitability of the question with the learning outcomes	100
• Clarity of instructions for working on the question	100
• Clarity of intent on the matter	100

The questionnaire was conducted on 40 students who acted as participants in MOOC learning. The assessment is based on 10 points that represent the user experience in accessing the developed MOOC content. Based on the results of the hearing, participants agreed that MOOC can be easily accessed in mobile and desktop versions so that participants can access MOOC content from anywhere and anytime. In addition, UM MOOCs also have a simple appearance so that they have a good level of readability, and the menus and features available can be easily understood and operated. The push notification feature between the MOOC and participant email allows the system to send activity updates to participants in real-time so that participants get immediate notification. MOOCs also offer features for two-way communication between participants and between participants and tutors.

4. CONCLUSION

The program has successfully developed MOOC content which includes teaching and learning plan, handouts, presentation slides, video explanation, audio podcast, and assessment tools. The results show that the MOOC content developed is easily accessible to students and can improve mastery of digital technology in the construction field

AUTHORS' CONTRIBUTIONS

M.M.A.P. and C.P.D. designed and directed the project. J.E.Y.P. performed the computations and development. V.A.K.D. and M.A.I. contributed to the result interpretation. All authors discussed the results and contributed to the final manuscript.

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