The application of design, building structures and project management study materials as an introduction to learning building information modelling

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ABSTRACT: The current growth rate of the construction sector has increased the demand for competent workers in this sector, including architects. The way that architects design is also changing mainly due to technological advances. The media used for design and presentation have evolved from manual accomplished with paper, rulers and pens, to designs stored in digital memory in the form of software. The development of building information modelling (BIM) learning at the tertiary level in Indonesia is urgently needed to meet the demands of the construction sector, especially in view of the Fourth Industrial Revolution (4IR). This research aims to provide recommendations for the application of design, building structures and construction management study materials as an introduction to BIM learning at the tertiary level in Indonesia. The research results show that design study materials, building structures and construction management are integrated with each other and support BIM learning.

INTRODUCTION

The Fourth Industrial Revolution (4IR) is a transformation of the industrial sector based on smart technology, automation, machine-to-machine communication, etc that leads to rapid improvements and fast and dynamic changes [1]. The data from the Central Bureau of Statistics (Badan Pusat Statistik - BPS), Indonesia, recorded that the growth rate in the construction sector reached 10.39% in the third quarter of 2021 [2]. There were 203,403 construction companies recorded in 2019-2021 [2]. Due to the rapid growth of the construction sector and construction companies, it has been predicted that the need for qualified and competent workers who can overcome the challenges of the industrial revolution will subsequently increase [3]. Therefore, these workers will need to be adequately prepared for the dynamically developing construction sector. The high demand for competent human resources (HR) poses a challenge for universities as institutions responsible for workforce readiness. Higher education institutions (HEI) are required to prepare high quality graduates competent not only at the national level, but also able to compete with international specialists in the era of technological progress [4].

Technological developments have also affected the world of architecture, and the emergence of technology has changed the way architects design. The media used for design and presentation have evolved from manual accomplished with paper, rulers and pens, to designs stored in digital memory in the form of software [5]. Currently, the Ministry of Public Works and Public Housing (Pekerjaan Umum dan Perumahan Rakyat - PUPR) in Indonesia requires the use of building information modelling (BIM) in building projects with an area of more than 2,000 m^2 and more than two floors, especially in regard to government buildings/state buildings/government/state-own enterprises (badan usaha milik negara - BUMN) projects. BIM can connect various applications and users, including architects and property owners, contractors and sub-contractors on-line and in real time [6].

BIM can be used as an information source about architectural drawings, landscape drawings, structural drawings, cost budget plan (rencana anggaran biaya - RAB), electrical or mechanical drawings, work volume and material requirements [7]. In some HEIs, the design process still relies on individual 2D and 3D-based drawing applications which is not advantageous, as BIM technology allows for collaborative and integrated workflows [8]. In this context, the implementation of BIM in university education is a demand that must be fulfilled as soon as possible, so that the graduates have the required BIM competencies [9].

The 5D BIM is also called a quantity take off [10]. For example, volume calculations can still be done manually with the help of Excel, but when using the BIM model, these calculations can done automatically, accurately and quickly. The particular advantage of 5D BIM is that the calculations are more accurate because a 3D model is used. The 5D BIM can be variously applied, for example, it can be integrated into automation machines, such as automatic bar bending machines [11]. Teaching and learning 5D BIM during architectural studies is based on recommendations from the Indonesian Institute of Architects (Institut Arsitek Indonesia - IAI) referring to design, building structure and project management study materials that have been presented at several universities with architectural study programmes.

AutoCAD is a software that is still developing and functions as a design application. The resulting 3D models can be used as discussion material for the entire project team to decide on the implementation/work methods that will be applied [12]. In line with this, design study materials can support BIM learning in designing a building and can simplify the design analysis process [13]. To obtain construction structure data required in building construction, the SAP2000 software can be used. Next, the building is structurally analysed and relevant data calculated according to the plan drawing using structural analysis to obtain the volume and estimated cost of the building.

Currently, BIM skills are urgently needed by students when they graduate from college and enter the job market. So, the application of study materials on BIM has become a necessity. Also, a greater focus should be given to the specific learning requirements of incorporating BIM into architectural studies. Therefore, in this research, design study materials were chosen as the initial step in the stages of drawing a building; building structure as the next step after the design drawing; and also project management, which is the calculation of the costs required for the building - all three steps are integrated with each other to shape the BIM learning package [14]. So, the main objective of this research was to apply design study materials, building structures and construction management in BIM learning.

METHOD

Participants in this research were architecture study programme students from the cities of Surabaya, Malang, Tulungagung and Lamongan, East Java Province, Indonesia. There were 155 students from different semesters because the design subject at the colleges had been implemented at the beginning of the first semester and continued until the seventh semester.

In this research, students were given continuous questions from the design stage using AutoCAD, then calculated the building structure using SAP2000, and then carried out cost calculations in Excel. It was hoped that students would understand integrated learning as a step in introducing BIM learning from planning design, building structures and construction management. An introduction to the BIM learning carried out in this research can be seen in Figure 1 below.

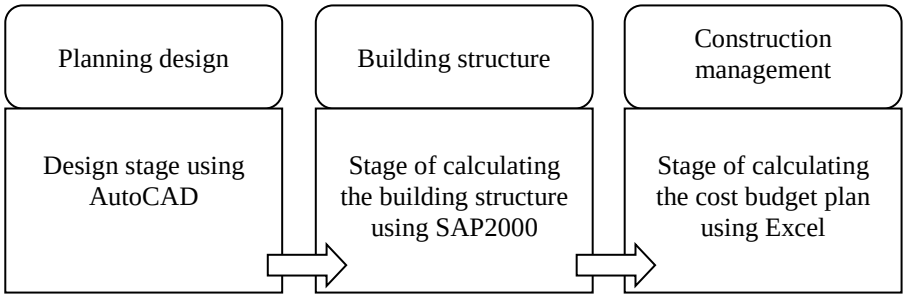

Figure 1: Stages of introduction to BIM learning.

The BIM learning in this research has been formed from several integrated science components; namely: design, building structure and construction management. The following are the introductory stages of BIM learning carried out in this research:

Planning design stage: The materials used are CAD drawings, which are made in the form of technical drawings using the AutoCAD application. The AutoCAD application can be seen in Figure 2 below.

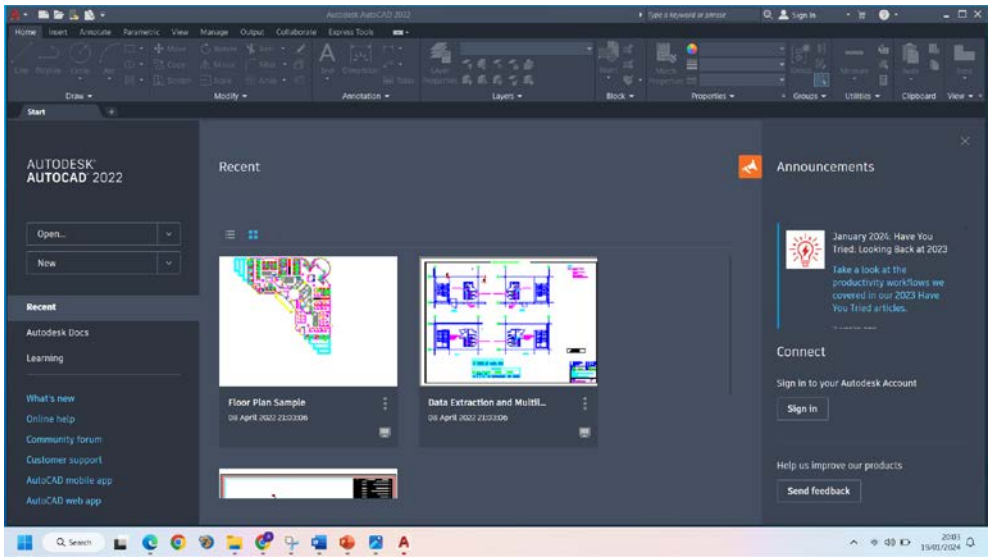

Figure 2: AutoCAD application.

Building structure stage: After the image model is combined and meets expectations, the next step is to carry out structural analysis calculations using the SAP2000 application. The SAP2000 application can be seen in Figure 3 below.

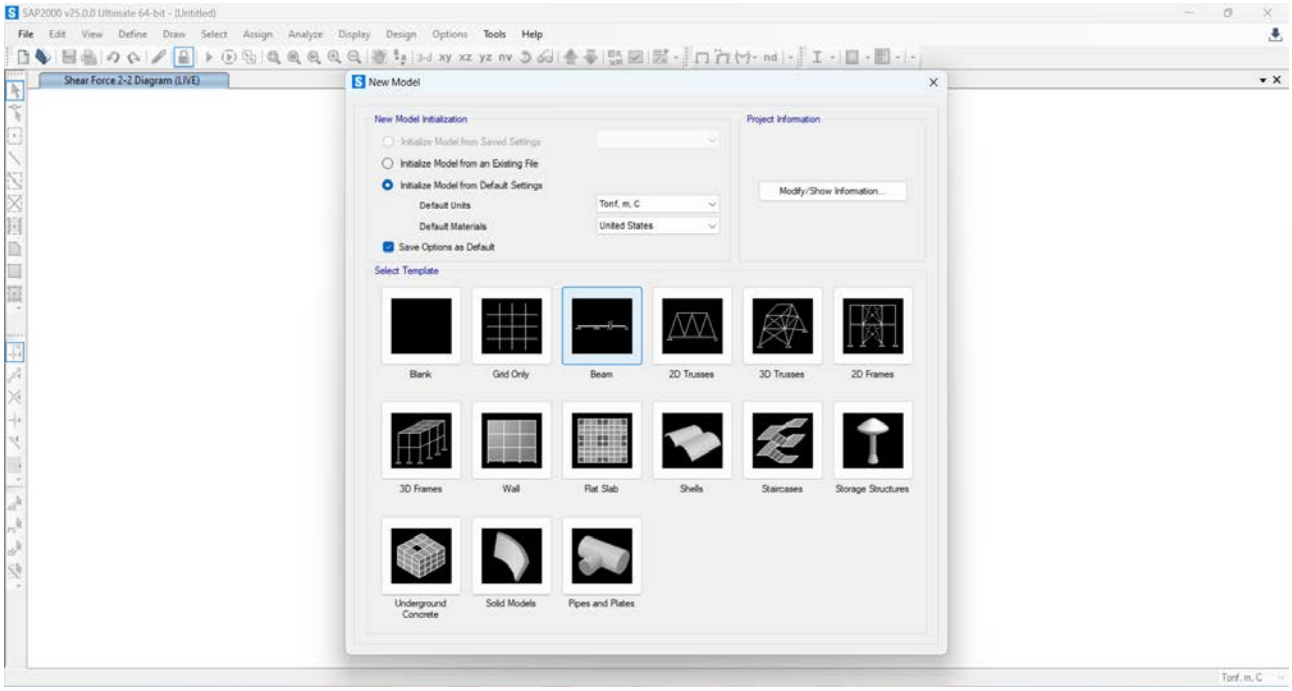

Figure 3: SAP2000 application.

Construction management stage: RAB analysis in the form of a Microsoft Excel file for further analysis with the volume obtained from the previously imported model. To determine the volume to make a RAB, the model is used as a reference, so that errors can be minimised to as small as possible.

RESULTS AND DISCUSSION

There were 155 students from architectural study programmes involved in this research, including 27 male and eight female students from the 3rd semester, 78 male and 25 female students from the 5th semester, and 14 male and three female students from the 7th semester.

Table 1: Research participants - descriptive data.

Semester	Gender	Number	Σ
3	M	27	35
	W	8	
5	M	78	103
	W	25	
7	M	14	17
	W	3	
Total number of students			155

Stage planning design: 3D modelling is a procedure for developing three-dimensional models using special software. This procedure is carried out as a process to create a model that represents the actual object in three dimensions. Three-dimensional design models are a representation of the width, length and height of an object. AutoCAD can be used to create 2D and 3D drawings. In this stage, students draw a 15/20 size beam using Ø 12 reinforcement with a span of 10m using AutoCAD (Figure 4).

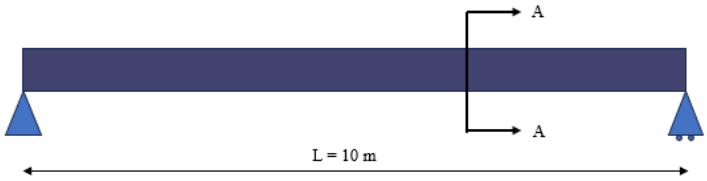

Figure 4: Design of a 15/20 size beam.

Beam drawings are made in the form of technical drawings using the AutoCAD application. This stage is carried out, so that students understand the introduction of BIM learning. Creating 2D design drawings using AutoCAD is BIM level 0 [15]. Drawing design creation can be done with 3D design using the SketchUp or 3ds Max application as BIM level 1. After the model drawing meets expectations, the next step is to carry out structural analysis calculations using the SAP2000 application.

Building structure stage: Structural design must ensure the stability of the building or construction, so that there is no possibility of collapse or destruction of the building. For a building to function optimally, the building structure must be sturdy. At this stage, the 3D model from the first stage is calculated using the SAP2000 application, which is loaded and structural analysis is carried out, the results of the analysis of normal forces, shear forces and internal moments of the structure will be obtained (Figure 5 and Figure 6).

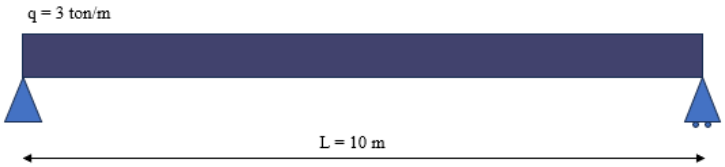

Figure 5: Structural analysis of a 15/20 size beam with load q.

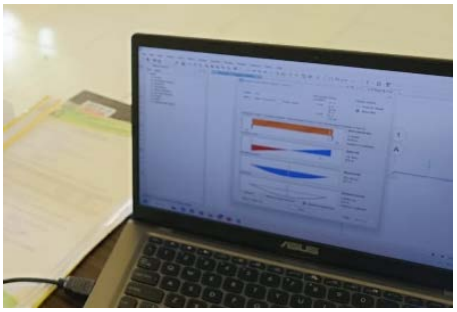

Figure 6: Students work in groups to complete assignments using SAP2000.

Structural calculations are carried out using the SAP2000 application with the aim that students understand the technical design process and structural calculations which are integrated into one functional and effective unit. The structural analysis data is in the form of BIM level 2 level, which can then be carried out for cost estimation work as BIM level 3 [15].

Construction management stage: Effectiveness and efficiency in a project are necessary to support success, so the third stage in this research is to carry out cost planning by calculating the volume from the previous stage.

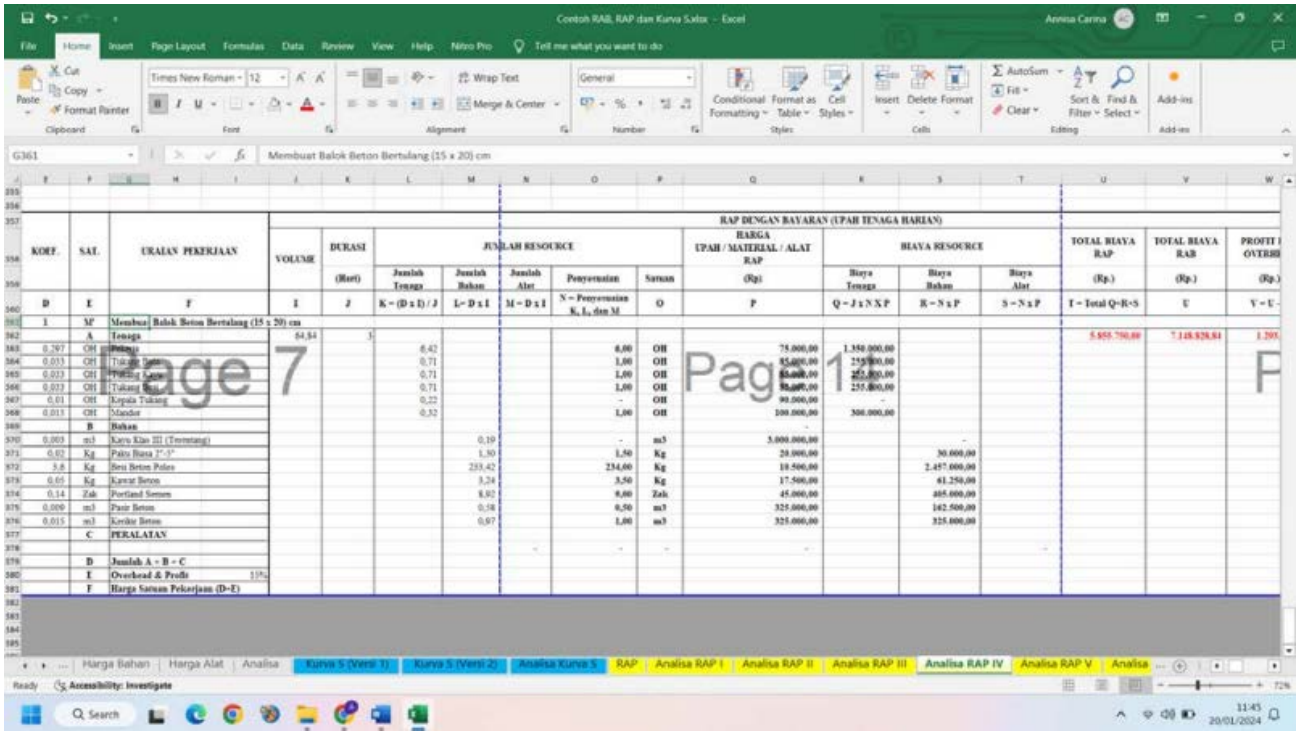

Figure 7: Cost analysis of 15/20 size blocks.

At this stage, students schedule construction and estimate costs. By this time, they are already at BIM level 3, where full compatibility is required between the data managed in the previous stage. Therefore, learning BIM requires a workflow that comes from a combination of various construction disciplines [16].

After all the necessary stages have been carried out, the results will automatically be integrated in the form of a simulation of the BIM model stages, which shows the model sequence along with the work execution time [17]. By applying knowledge from the study materials on planning design, building structures and construction management, students better understand the form of BIM learning where different tasks/jobs are integrated with each other. The benefit of BIM is to avoid mistakes from drawing design to construction implementation [18][19]. So, the types of study materials that can support BIM learning include: design, building structures and construction management.

Although study materials can be selected for a study programme when creating courses, the specific determination of study materials must be related to the appropriate scientific field or expertise. In transferring BIM learning to higher education, technical content and collaborative processes from various stakeholders must be mapped and combined to result in BIM competencies that can truly be applied in professional practice [20]. By applying study materials for design planning, building structures and construction management in BIM learning, it is hoped that it can result in the formation of core competencies of graduates as human resources potencially succesful in a competitive job market [21].

The IAI reference design study material includes competency formulations regarding creative thinking theory, innovation and being a pioneer in design methods. The IAI reference building structure study material includes competency formulations regarding the understanding of the technical design process and the integration of structures, construction technology and utility systems into one effective functional unit. The IAI reference project management study material includes competency formulations regarding mastery of project management principles, construction techniques and processes, preparation of design and tender documents, building and environmental preservation, building and city regulations, and professional ethics [22].

CONCLUSIONS

The Forth Industrial Revolution has changed the way of design and construction. Building information modelling is one of the software required by the Indonesian government for development projects. In architecture departments at universities in East Java, Indonesia, BIM is starting to be introduced into learning. In this research, the introduction to BIM learning is carried out through design study materials, building structures and construction management, so that students can simulate BIM learning, where tasks/jobs are integrated with each other. The implementation of introductory BIM learning increases student competency in operating software that supports BIM learning.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the Higher Education Architecture Study Programme in Surabaya, Lamongan, Gresik and Tulungagung, East Java Province, Indonesia, for providing the opportunity to conduct this research.

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