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Architectural Design of School Buildings in the View of Concepts and Applications of Artificial Intelligence

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Architectural Design of School Buildings in the View of Concepts and Applications of Artificial Intelligence

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***ABSTRACT*: An enormous amount of data is usually needed for the design in the early phases of projects. Right now, computational tools are accessible to help the designer use data and information quickly and effectively to do this. Artificial intelligence, or AI, is a recent field of study that uses, analyzes, and manipulates data to complete tasks and reach goals. Modeling, anomaly detection, association, and grouping are just a few of the many sub-fields that make up the current state of AI, which has been incorporated into many other disciplines. The goal of the current study is to make clear the benefits of using AI into architectural design and to motivate architects to begin doing so. A two-pronged approach is used to achieve this: showcasing the relevant literature and the applicable and desired project. Therefore, the continued promotion and implementation of new computer technologies, such as BIM technology, have had an inescapable significant impact on the Egyptian building sector. In this work, we provide the experiments using the Revit program and their conclusions based on the amount of college education. The architectural design major at higher vocational institutions has seen significant changes at this time. The educational objectives of the institution don't align with the field of architectural design's recent growth. We outline the most recent research on BIM-based architecture education in this article. We contrasted the various software programs used in the education sector, including CAD, SketchUp, and Revit. In this essay, we demonstrate that the BIM experiment is a cutting-edge technological advancement, and that by utilizing it, everyone may effectively revolutionize the building business. As a consequence of the experiments and projects using the Revit program during instruction, we receive a BIM competency certificate. The outcomes of experiments, testing, performance, and BIM's impacts on trainings are presented in the study. A visualization tool is used to expand the body of knowledge of BIM education while employing BIM in a learning environment.**

***KEYWORDS:* Artificial Intelligence, Revit, School building, BIM, Architectural Design.**

1-INTRODUCTION

A machine that replicates human cognitive processes including problem-solving, pattern recognition, and learning is known as artificial intelligence (AI). A branch of artificial intelligence called machine learning employs statistical methods to give computers the capacity to learn from data without being explicitly programmed. The computer becomes better at interpreting and generating insights the more data it is exposed to. Thinking is the process of using a huge number of data to perceive, comprehend, anticipate, and act in a world that is more complex and greater than itself. Artificial intelligence (AI) is simply the use of data to teach machines new things. AI goes further as it attempts not just to understand but also to build intelligent entities. AI is a significant science appeared in the late 40s of the 20th centuries, while it got its name in 1956.[1]

This paper may be seen as a response to the architects who would view artificial intelligence as a delusion. It should be made very clear that AI will never take the place of creative architects in design and planning. In order to approach new projects, architects often employ historical construction data, design and building data, and user demands. However, a lot of designers and planners still consider this method to be in the past. It might work wonders if enormous volumes of data could be used in a very short amount of time to improve architectural design.

In reality, during the first phases of design, architects must deal with a vast amount of information pertaining to the specifics of the many project components. Many pieces of software have been created recently to help designers manage and use data and information in order to create their designs quickly, correctly, and efficiently while also saving a lot of time .

The fundamental goal of this study is to inspire architects to become more acquainted with and knowledgeable about cutting-edge computational methods and software, which form the foundation of AI. This essay uses a two-pronged approach to accomplish this goal: first, a brief literature study of relevant software and AI; second, an actual and hypothetical project.

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2.1. AI in Data Management and Design Options

There are more computational technologies being used in architecture. The amount of data collected globally over the past ten years is tremendous and expected to grow [2]. The built environment and human actions, which serve as architecture's playing field, make up the majority of the data. AI and computational technologies are, nevertheless, desperately needed in architecture to produce analytical data that has a substantial impact on choices made at any stage of design. Additionally, algorithmic parametric design tools and computer-aided design (CAD) software may create shapes that would not be possible without computing [3]

In the first stages of design, architects typically have to handle a large amount of data. This information comprises analyses of the physical environment, user demands, functional specifications, prior case studies, legal codes, etc. These data must all be handled. Here, artificial intelligence (AI) plays a key role in helping to cope with all of these data sets, which may be quite challenging to analyze without the aid of computing tools. As a result, the time needed for the first stages of design is reduced, which has a favorable impact on the design process.

There is cutting-edge commercial software on the application of AI in architecture. An algorithmic design application is CATIA, which stands for Computer Aided Three-dimensional Interactive Application. It demonstrates the coherence and application of new technologies, materials, equipment, innovative techniques, and information tools that provide more effective use of materials [4]. A different piece of software is Grasshopper, a graphical parametric tool that runs alongside Rhinoceros. At a teaching activity, Schneider developed an urban design plan using Grasshopper [5]

Along with the tools already in use, other academics are investigating ways to use AI in architecture and advance design [6, 7&8]. Additionally, Chillou, 2019 used AI to analyze floor layouts in order to produce a variety of floor plan possibilities [9]. Project Discover is a generative design tool for space planning that Nagi and his colleagues created in 2017 [10]. The software DANIEL, which is a deep architecture for autonomous analysis and retrieval of building floor plans, was created by Sharma et al. in 2017 [11]. Generative Adversarial Networks (GANs) may be used to create distinctive and innovative design variants, as shown by et al. in 2018[12]

2.2. Application of AI in Design Options

One of the interesting examples that shows the potential of AI in the architectural organization of space is Stanislas Chaillou's contribution in developing a new system [13]. Chailllou was able to utilize deep learning and GANs in generating floor plans by focusing on functionality and style as main parameters as shown in "Fig. 1". Soon architects may benefit from this feasible tool opening up many iterations of the projects and producing appropriate floor plans. Accordingly, it establishes a base for a more analytical process and generation of creative ideas by the architect. This experience highlights the potential of AI in providing a tool that helps informing knowledgeable decisions within a limited time during the design phase.

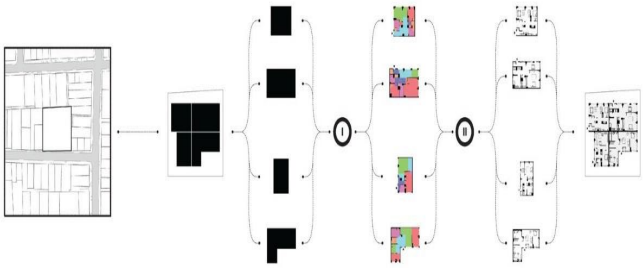

Fig. 1. Utilizing Deep Learning and GANs in Generating Floor Plans [13]

Moreover, an architectural office in Copenhagen (3XN) developed an important research project that emphasizes how a distinguished architectural practice positions itself according to the development of technologies. This project identified three main aspects where AI could contribute positively in: Research (organizing information), Design (a better iterative process) and Knowledge Management (developing an internal database of experience). The research division in the office is preparing for a paradigm shift and planning for five years ahead to develop the studio for the onset of AI into architecture practice [13].

2.3. Application of AI: AI as a Style Guide

Additionally, AI can be used to find and duplicate elements, such as compositions and materials, profiles, story heights, window and stair specifications, and more. For example, Revit is an all-in-one CAD design solution that answers all architects needs related to 2D drafting, 3D modelling and BIM. The objective of Revit is to use AI to assist architects with time-consuming and precise tasks, in order for them to innovate focus on the important design choices [14]. With the help of Autodesk Revit software, you can create architectural designs that are more precise and of greater quality. You may record and evaluate concepts using tools created to support Building Information Modeling workflows, and you can preserve your vision throughout design, documentation, and construction. Important choices that have an impact on a building's sustainability are made at the early design phases of a project.

2.4. Research Background

In 1973, the world's first oil crisis broke out. Due to the increase in oil demand from the United States, the largest oil consumer at the time, as well as the global oil shortage and price increase caused by untimely domestic oil exploration. In 1975, all industries in the United States were exploring energy conservation and efficiency [15].

The introduction of BIM principles into the multidisciplinary cooperation that architectural engineering students participate in has been the subject of several pilot projects that have concentrated on a variety of pertinent topics; establishing guidelines for the incorporation of BIM topics into the curriculum for construction engineering and management; incorporating integrated BIM into the instruction of structural engineering and building technology students; and suggesting a framework for the planning of BIM project execution to improve student competencies in BIM-focused education [16-17].

2. Literature review

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According to the "Building Information Model Professional Skill Level Standard " issued by the Ministry of Education of China. The building information model is the process of creating and managing building information in the entire life cycle of planning, design, construction, completion, use, and maintenance using a three-dimensional, real-time, and dynamic model to truly simulate the design and construction of a project. The building information model includes building volume information, spatial interaction information, geographic and landform information, component engineering quantity information, and material information of each component of the building. In 2002, Autodesk acquired Revit Technology, a three-dimensional software company, and for the first-time interpreted BIM and became the "BIM" that all architects know.

Autodesk Revit is one of many software developed by Autodesk. Autodesk Revit is specifically developed for how to create building information models. Revit helps architects and designers to create three-dimensional building plans and use plug-in software, which is secondarily developed through the Revit software platform. It can simulate construction, maintenance, and design with better efficiency.

Revit is one of the most widely used BIM software systems in China's construction industry. Other software such as NavisWorks, Fuzor, Lumion, Bim5d are also called BIM series software, but the single software with the most comprehensive functions in Revit. Additionally, a variety of programs, including SJMS, THS WARE, Revit, Glodon, Lubansoft, and PMS, can successfully improve working efficiency, reduce cost treatment errors, and achieve highly effective information fusion and sharing [18-19].

Additionally encouraging BIM-based workflows, China is actively supporting and pushing the adoption of prefabrication techniques across all AEC industry sectors [19]. The Chinese government has lately emerged as a key factor encouraging BIM adoption in China in addition to software businesses that provide BIM products [20], with a directive by the Ministry of Housing and Urban-Rural Development setting an ambitious goal of a national BIM adoption rate of 90% by the year 2020 [21].

2.5. AI IN BUILDING INFORMATION MODELLING

The phrase "building information modeling" (BIM) is well-known in the field of modern architecture. The link between the many contributors to the building industry, including architects, engineers, and contractors, is strengthened by this multidisciplinary approach. Rather than just being a technical shift, Eastman et al. (2008) classified it as a process change. Building design simulation in a virtual environment is referred to as BIM. According to Azhar et al. (2008), the resulting BIM is an intelligent, parametric, object-oriented, and data-rich digital representation of the facility. As a result, perspectives and data that are suitable for different users' needs may be retrieved and examined to provide data that can be utilized to influence choices and enhance the facility's development process. Regarding the great complexity of the multi-layered, multi-disciplinary structure of BIM software, AI offers a strong level of assistance.

BIM is a 3D model-based method that offers advice from experts in. architecture, engineering, and construction on how to efficiently plan, design, build, and maintain infrastructure and buildings. The 3D models should take into account the architecture, engineering, mechanical, electrical, and plumbing (MEP) plans as well as the order of duties for the appropriate teams while planning and designing the construction of a structure. It is exceedingly difficult to prevent the various models from the sub-teams from clashing with one another. In order to avoid rework, generative design uses machine learning to detect and resolve conflicts between the many models created and developed by the various teams during the planning and design process.

2.5.1. Characteristics of Building Information Models

Building information models work with digital representations of buil ding parts (objects) that include computable visual and data features id entifying them to software programs to store them as digital databases [22]. The characteristics of BIM are shown in Fig. 2

Characteristics of BIM	Uses a digital database to operate
	Is object based
	Offers improved parametric modeling

Fig.2: Characteristics of BIM

2.5.2. BIM applications

Some are well established applications used extensively in professional practice; others are still in academic research stages [23]. The applications are:

- Programming and space planning
- Form exploration
- Documents production
- Design coordination
- Design review and visualization
- Sustainable design
- Scheduling (4D Modeling)
- Cost estimation
- Design and code checking
-

2.5.3. BIM Tools

Building information modeling is a set of processes rather than a specific piece of software. By exchanging design data with one another, the many project participants in this system efficiently interact and communicate, which helps to lower mistakes and boost efficiency. BIM software is included in Table 1 [24].

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TABLE 1: BIM TOOLS		
BIM Tools(Software)	Autodesk BIM Tools	Autodesk Revit Architecture Autodesk Revit Structure Autodesk Revit MEP AutoCAD Civil 3D
	Graphisoft BIM Tools	ArchiCAD ArchiCAD MEP Modeler Eco Designer Artlantis Virtual Building Explorer
	Energy modeling applications	IES <VE> Integrated Environment Solution Ecotect eQUEST Design Builder Green Building Studio
	Vico BIM Solution	
	Tekla BIM Solution	
	Other BIM solutions	Bentley BIM Solution Solibri Model Checker Nemetscheck BIM Solution

2.6. The Benefits of BIM in Architecture

The age of BIM is post-orthographic. It incorporates 4D (time), 5D (cost), 6D (sustainability), 7D (operation), and 8D (safety) in addition to the traditional 3-Dimensional graphics. What's best? Not just architects can use BIM. Through cloud collaboration and clash detection, it promotes the integration of the responsibilities of all the many project stakeholders—including those involved in architecture, civil engineering, structural design, and other services. Now that everyone can work on the same model concurrently, greater coordination and a more precise layout are ensured. There are several benefits to BIM in the AEC sector. However, let's mention six of the more important ones to give you a general sense.

2.6.1. BIM Brings Down the Project Cost and Saves Resources.

Graph that contrasts the costs of a project utilizing several project methodologies, such as the conventional technique and BIM methodology.

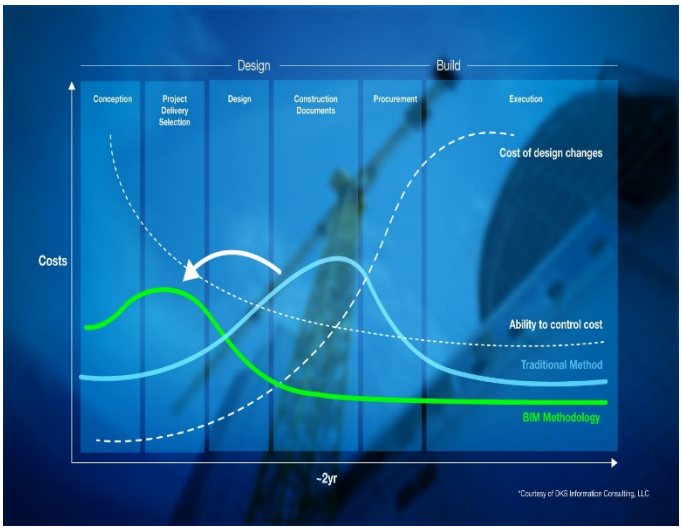

Fig.3: Using BIM saves on Project Cost

Project estimates may be calculated using BIM technology. The advantages of BIM also include rapid and accurate labor, material, and shipping cost estimates that update automatically with modifications. In comparison to traditional methods, this gives architects and other stakeholders a much better idea of the project cost and scheduling and saves time that can be used to choose more affordable materials, make pre-fabrication provisions (if necessary), and generally reduce human errors and project delays.

2.6.2. BIM Ensures Greater Efficiency and Shorter Project Duration

Utilizing the different capabilities offered by BIM technology aids in minimizing the amount of time needed for project design (the pre-construction phase). BIM technology adds a fourth dimension—time—in addition to the usual three dimensions of modeling. The decrease in overall project construction time, a streamlined workflow, and an efficient procedure are all advantages of 4D BIM.

2.6.3. BIM Improves Interdisciplinary Coordination and Communication

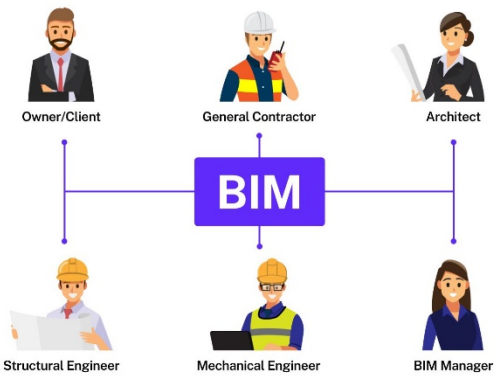

Fig.4: BIM allows seamless collaboration between all disciplines

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BIM creates a virtual model of a project with all of its aspects, from conception through operation. The ability to collaborate across disciplines via the cloud is one of BIM's standout benefits. This implies that all consultants, whether electrical, MEP, or HVAC, may provide and receive all project updates and information in real-time. Additionally, design choices and updates may be made considerably more quickly because to its clash-detection function. To carry out and coordinate the numerous building tasks, even the contractors can use the same model.

2.6.4. BIM Increases Productivity and the Scope for Pre-fabrication

BIM may be used to build precise production models and also leaves room for decision-making prior to the start of the construction process. These models are suitable for pre-fabrication right now.

2.6.5. BIM Yields Higher Quality Results

Using BIM improves not only the efficiency of the construction process but also the quality of the finished product and the entire project. One of the key advantages of BIM is the comprehensive computations and accurate, detailed models. This invariably results in a completed product of superior quality.

2.6.6. BIM Helps with Sustainable Construction

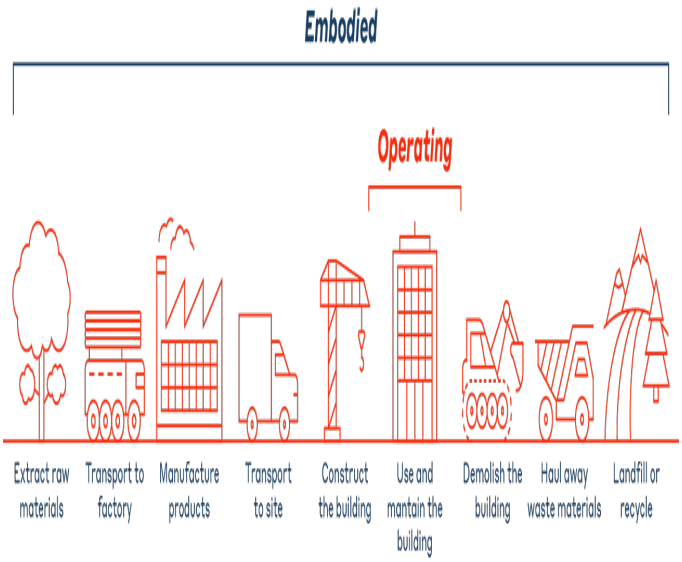

Fig.5: Lifecycle of a building (Source: BIM Corner)

During the design and construction phases, BIM increases efficiency and gives better transparency. It also provides greater control during the operations phase. All of this helps create a building process and result that are more environmentally friendly.

All the interested parties are able to discuss and come up with ideas for building methods and materials that are less costly both economically and ecologically since they have access to all the project information at once. A Building Information Model's degree of detail makes it possible to evaluate the logic and order of construction, leaving very little possibility for unexpected events to occur. The building owner and other stakeholders may then be informed of all this information, which will help them manage the building effectively while it is in use.

Time savings in routine chores like visualization, facilities management, construction sequencing, conflict-interference-collision detection, forensic analysis, and code reviews by the many safety departments are a few other applications and benefits of BIM in the AEC business.

2.7. Why isn't BIM 'the standard' yet?

Since the execution of it still faces significant challenges. The first and most significant is the lack of adequate or even passable student exposure to BIM or any of its related tools. The outcome? Students struggle through the industry's outdated, time-consuming processes after graduating with very little to no knowledge of BIM technologies, landing underpaid positions.

But this too will be gone very soon! A unique BIM Professional Course from Novatr has been developed with a focused curriculum that is applicable to real-world BIM applications. The course concludes with the creation of an outstanding portfolio that meets professional standards and a real-world BIM project.

If you work in the AEC sector, you have the choice to either contribute to its historical era or, by taking the BIM Professional Course, to prepare yourself for the future.

3. Material and Methods

Computer Software (Revit BIM) used in the Teaching of Architectural Design, Offer BIM application courses. Introduce the basic knowledge of BIM technology into the design principal course of the first-year university students to improve students' perceptual understanding of BIM; the second-year university offers the "BIM Technology Application" course using Revit software for teaching. Integrate BIM theory and software practice into education, focusing on project teaching. This allows for Revit mastery. For example, students can use BIM technology to learn and integrate other course knowledge through the combination of Revit courses and architectural drawing, materials, and construction technology, architectural design and other methods, and comprehensive study and practice.

Revit software has the characteristics of visualization, interaction, simulation, optimization, sharing, and integration. Incorporate design theory into the teaching of Revit architectural design practice. For example, Figure (6) shows the homework "Architectural design of school buildings" by students learning the course "Architectural Drawing and Recognition of Drawings" through Revit. Students can use its visual characteristics to directly understand the knowledge of three-dimensional projection and use the three-dimensional view.

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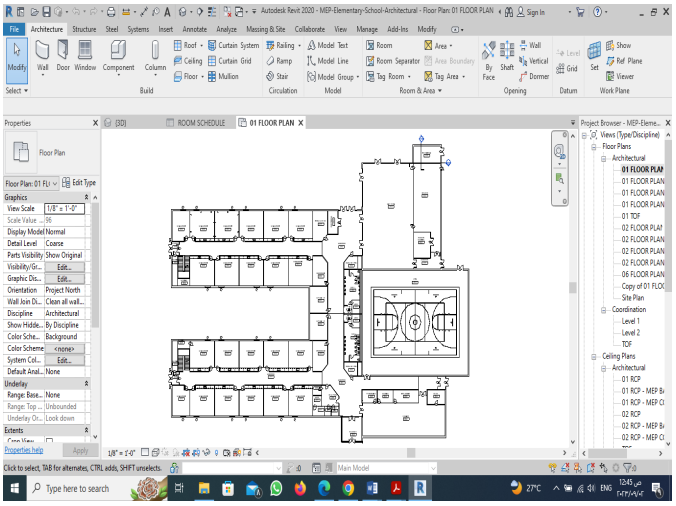
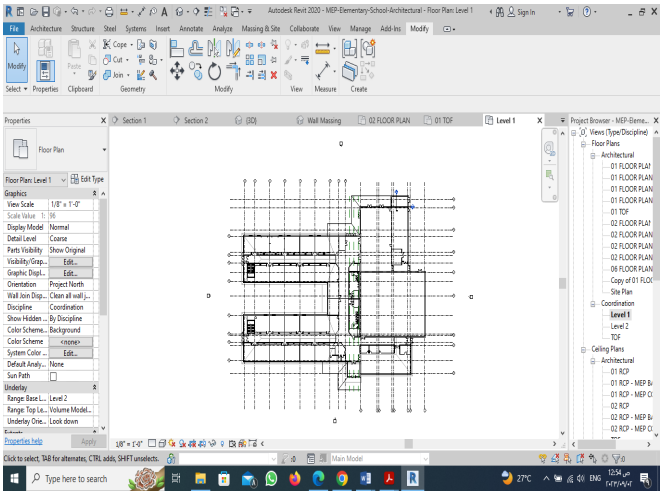
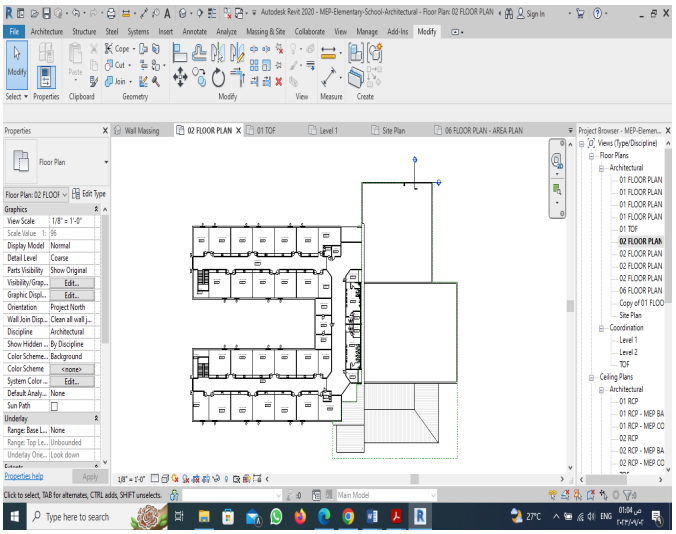


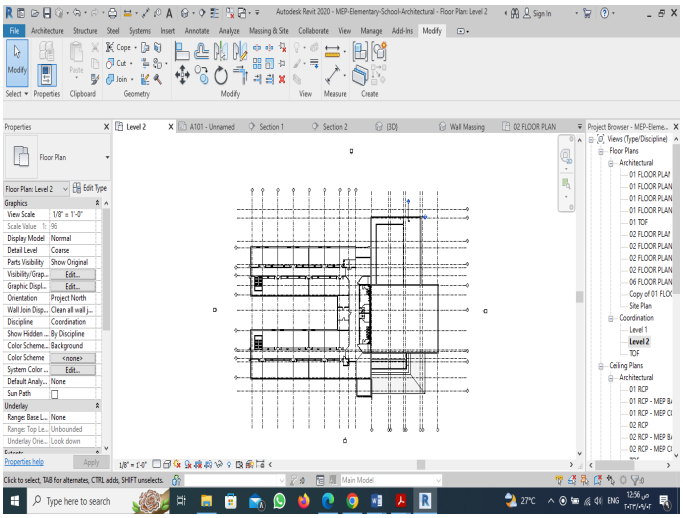
01 FLOOR PLAN



Level 1



02 FLOOR PLAN



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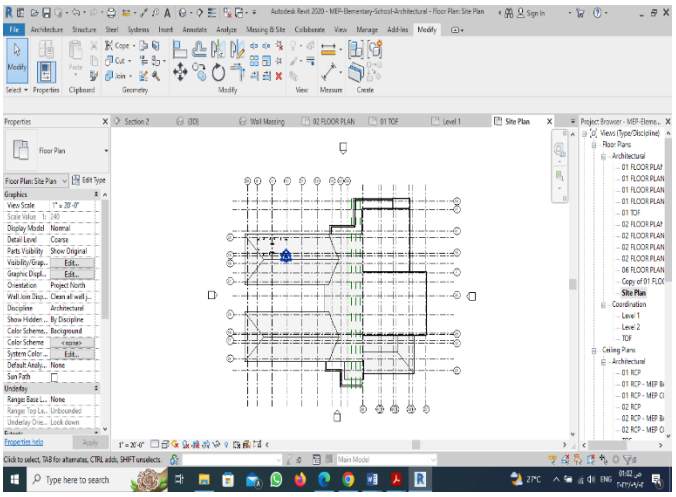

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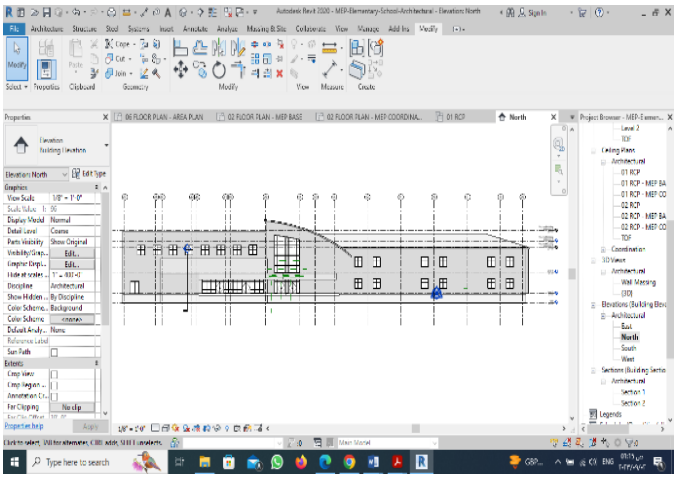

Elevation North

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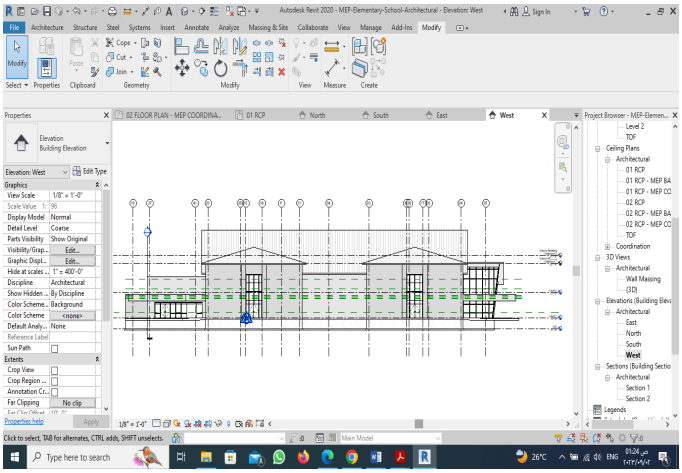
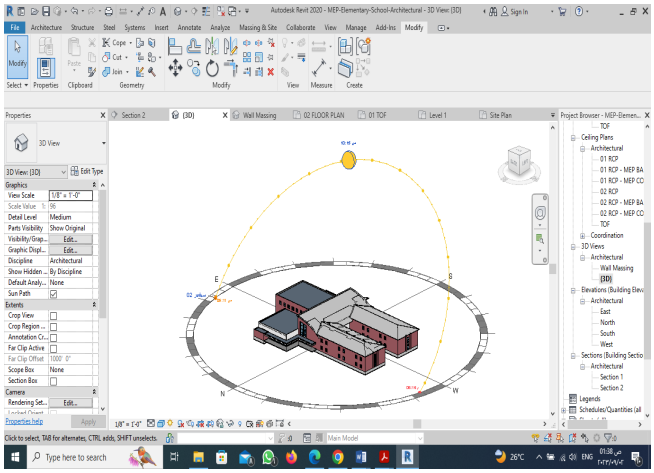
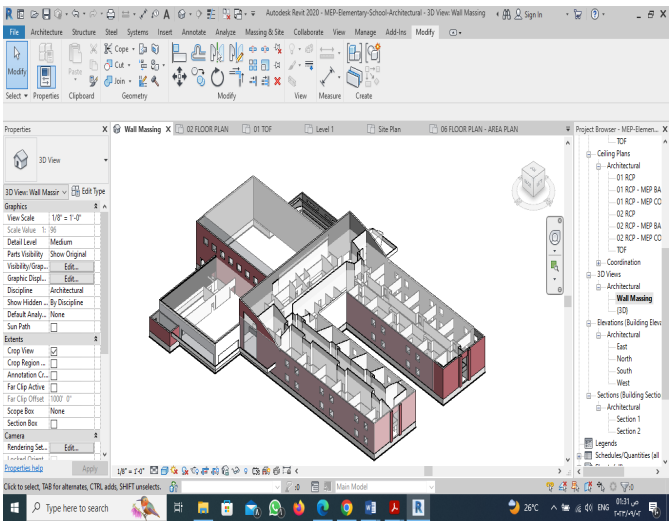


Elevation West

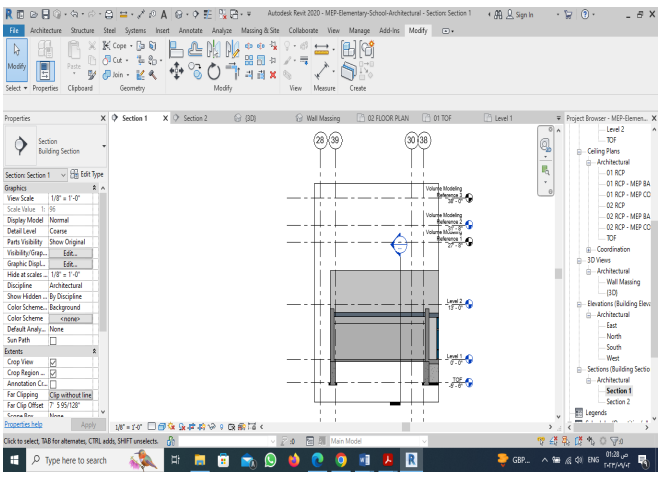


3D

Figure 6. The initial student's usual homework: Integrate the Revit building plan, elevation and door and window statistics



Wall Massing



Section 1

4. Results and Discussion

4.1. Results

4.1.1. Insufficient Connection Between the Requirements of Teaching Norms and the Requirements of Corporate Job Needs

With the industrial upgrading of the construction industry and the widespread promotion and application of new BIM technologies, companies in the construction industry need a large number of employees who have mastered new technologies. Prior to 2018, higher vocational colleges rarely offered courses such as "BIM Technology Application", "Building Energy Efficiency Design", "Prefabricated Building", "Building Intelligence" and other courses. Graduates cannot well meet the needs of employers in the construction industry. Talent training cannot meet the needs of the construction industry. It is necessary to open relevant courses or increase the proportion of class hours to make up for the talent gap.

4.1.2. Less Use of BIM Technology in Training Courses

BIM technology is rarely used in training courses such as curriculum design and graduation design. Since there is no special BIM course, teachers can only briefly introduce the basic knowledge of BIM when teaching related courses. For the application of BIM-related software, teachers can only teach introductory applications, such as CAD, tangent, SketchUp, etc. Most applications rely on students' self-study, and students only master lesser modeling software, such as CAD. Therefore, in the training courses, most students still use CAD or tangent for the design of two-dimensional drawings and use SketchUp for three-dimensional visualization of buildings. SketchUp's three-dimensional visualization can only display the three-dimensional effects of buildings, and cannot display the buildings themselves.

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4.1.3. There Is Currently a Lack of Teacher Qualifications Related to BIM Technology

There are only two teachers in the architectural design major of our school who hold BIM skills certificates. Few teachers learn BIM software systems, and most teachers do not have the ability to independently complete BIM technology teaching.

4.2. Discussion

Establish a Professional Curriculum System with BIM Application as the Core Offer BIM application courses. Introduce the basic knowledge of BIM technology into the design principal course of the first-year university students to improve students' perceptual understanding of BIM; the second-year university offers the "BIM Technology Application" course using Revit software for teaching. Integrate BIM theory and software practice into teaching, focusing on project teaching. This allows for Revit mastery. For example, through the combination of Revit courses and architectural drawing, materials, and construction technology, architectural design and other courses, comprehensive study and practice, students can use BIM technology to learn and integrate another course knowledge. Revit software has the characteristics of visualization, interaction, simulation, optimization, sharing, and integration. Incorporate design theory into the teaching of Revit architectural design practice, The advantages of applying BIM technology platform synchronously in stages from design to construction and project management include:

- **Centralized data management:** if the project is changed, there is no need to manually update batches of 2D CAD drawings. Just concentrate on the accuracy and efficiency of everything else, including the 3D design models.
- **Design visual model**: The entire project will be represented in a digital model in the most exact and detailed manner possible. Depending on the degree of the model, each project component and even the tiniest detail may be seen. The structural design team, MEP,... can readily find conflicts and optimize the design of features in the space of the building, and the investor will easily obtain the most intuitive perspective of the project.
- **Save cost – time:** All BIM models are comprehensive and extremely precise, which gives contractors and investors a better understanding when predicting investment and cost ranges. Consistent data management will reduce expenses and time spent working, prevent data loss in storage, and improve document management.
- **Increased capacity for collaboration:** BIM makes it easier for project participants to work together more closely. Architectural design, structural design, MEP, cost calculation, etc., all work on the same model consistently, and **information is updated often, creating a continuous stream of information.**
- **Reducing Risk:** A 3D BIM model includes every component of a real structure, making it simple to identify conflicts between building components, restrict occurrences during construction, and reduce mistakes. omitted.

For example, Figure shows the homework by students learn the course "Architectural Drawing and Recognition of Drawings" through Revit. Students can use its visual characteristics to directly understand the knowledge of three-dimensional projection and use the three-dimensional view.

Establish a BIM Practice Teaching System Aimed at Design Projects At present, BIM teaching in Egypt's higher vocational colleges is still in the exploratory stage. The BIM basic courses should be set up reasonably and BIM technology should be combined with professional courses. The project goals should be the graduation design, subject competitions, and "1+X" skill level exams to enrich BIM teaching and form a variety of project-oriented practical teaching.

In this graduation project, we used BIM technology to demonstrate our architectural design plan, simulating the physical characteristics of building energy-saving, ventilation, sunshine, and achieving the dual improvement effect of BIM technology application level and professional skills. Figure 4 presents model performed by students' usual homework in the middle of learning based on Revit architectural model. Especially during the current Covid-19 period, it is not suitable for students to go out to the market to buy handmade building model materials. Using BIM technology to simulate building models is obviously a better solution.

At present, there is a very fierce BIM skill competition in Egypt. For example, the "Luban Cup" National Colleges and Universities BIM Technology Competition, "National Colleges and Universities BIM Graduation Design Innovation Competition" and other competitions are fierce, and college students can participate. Among them, the "Luban Cup" also has a track for higher vocational colleges, encouraging college students to form teams to participate in competitions to promote learning and improve professional practice capabilities.

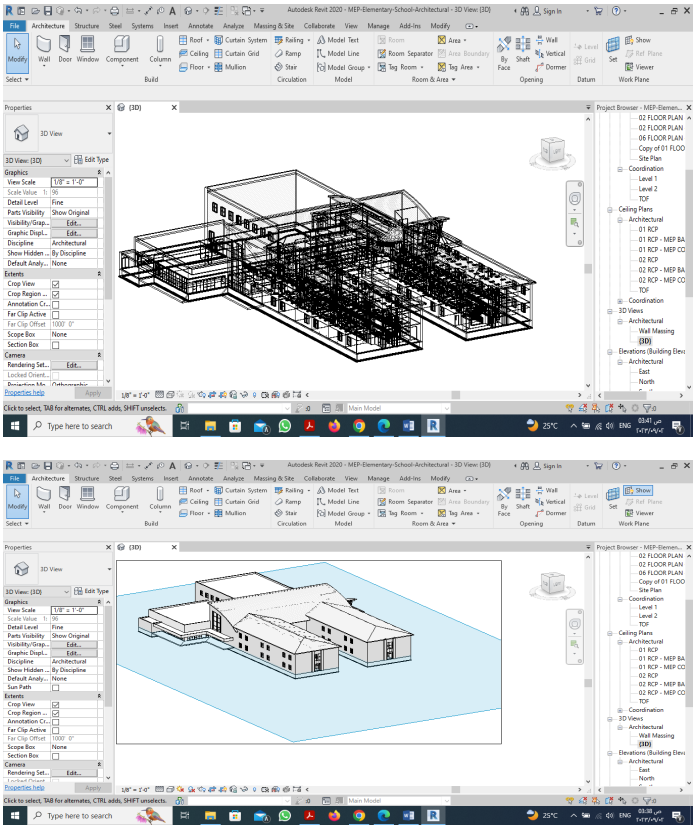

Figure 7. Students' usual homework in the middle of learning: Revit architectural model.

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According to the "1+X" certification system, students must obtain a BIM vocational skill level certificate before graduation. Through classroom learning and pre-examination training after class, it is ensured that students successfully obtain skills certificates, so that students can truly gain professional knowledge from their studies and have a sense of accomplishment.

At present, few teachers master BIM application technology and cannot complete teaching tasks. Schools can hire BIM modelers from companies as part-time teachers. A case study is presented that reviews the course, assesses student performance, and points out areas that should be improved with regard to software training, time management, technology connection, interoperability concerns, and the impact of BIM on teamwork [25]. Numerous studies describe the goals, processes, and results of developing new knowledge in higher education that is BIM-focused in architectural design and study. Case studies are used in research to test a course, assess student performance, and pinpoint areas for improvement in software training, time management, technological connectivity, interoperability problems, and how BIM influences cooperation [26–17]. A visualization tool is utilized when employing BIM in an interdisciplinary setting to expand the body of knowledge in BIM education.

At the same time, the school should formulate a plan to train a select group of young and middle-aged teachers, hire corporate BIM modelers to train teachers, and learn BIM software such as Revit, Lumion, Fuzor, Glodon, NavisWorks, etc. Make teachers have the ability to apply BIM technology. Establish a team of teachers who can understand and proficiently use BIM technology to provide a solid foundation for cultivating high-quality skilled talents.

5. Conclusions

Currently, BIM technology is rapidly being promoted all over the world, and Egypt is entering the era of architectural BIM. The increasing demand for BIM technical talents requires that the teaching reform of architectural design majors integrate BIM technology into professional teaching, cultivate students' BIM technical capabilities, and promote the industrial upgrading of the construction industry. In future, the proposed technology-based experiment is promising, and everyone can work together to contribute to the energy-saving and BIM computer technology's effective revolution of the construction sector.

Even though significant job losses are anticipated, AI is unlikely to totally replace the working force. Instead, it will alter construction industry business tactics, reduce costly errors, reduce worker accidents, and enhance building operations

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