WIP: Designing an On-Screen Interactive Guide (OSIG) Tool to Promote Practical Hands-on Learning Experiences on Building Information Modeling

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Abstract:

The Architecture, Engineering, and Construction (AEC) sector expects a digital transformation with Building Information Modeling (BIM), which can save 10~25% for office buildings and 15~25% for highway construction projects. However, the lack of skilled BIM workforces is a major challenge for the growing demand for infrastructure investment. Authors are experienced BIM researchers and instructors. Their observations found that cognitive overload is common among learners of BIM software. Currently, teaching and learning are both hard and time-consuming. Learner's attentions frequently swing between software screens and the (a) step-by-step manual with text and annotations, or (2) the instructor's demonstrations. Digital transformations and adoptions in business operations are becoming much more successful when using the On-Screen Interactive Guide (OSIG) at onboard training. Hence, this Work-in-Progress (WIP) paper presents a research project that aims to develop an OSIG tool to employ "Learning by Doing" to promote practical hands-on learning experiences on BIM software, as a pathway towards successfully educating and producing more skilled BIM workforces. The proposed OSIG framework for teaching and learning BIM software includes an OSIG editor that generates BIM laboratory manuals and saves them as English-like scripts for the OSIG player to "play." Moreover, an AI-powered OSIG version with adaptive instructions has been discussed with an emphasis on Design Thinking and optimized Cognitive Load. Presenting this WIP paper at the ASEE annual conference will help the authors to gain feedback and input from the engineering design software education community, as well as establish partnerships with more institutions for the nationwide implementation of the OSIG. Then, comparative experiments will be used to examine the effects of on-screen instructions on students' learning of BIM software skills. This project is transformative in the following aspects. First, how BIM Revit functions and skills are taught and learned is novel and transformative by using the OSIG to reduce instructors' stress in teaching and students' cognitive overload in learning. Second, with a good understanding of each learner's learning characteristics, the OSIG can generate the most effective, personalized scripts for each learner.

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Introduction

The Architecture, Engineering, and Construction (AEC) sector is moving towards greater digitalization and data-driven practices in the 21st century to deliver productivity, quality, safety, and sustainability in construction projects by adopting Virtual Design and Construction (VDC) technologies, specifically BIM [1,2]. With digital transformation, construction cost is estimated to save 10~25% for vertical construction projects (e.g., office buildings) and higher rates of 15~25% for horizontal projects (e.g., highways) [3]. The global demand and use of VDC/BIM were expected to lead to annual savings of $0.95 trillion in design and construction and $0.40 trillion in the operation and maintenance phases in the non-residential AEC sector in 2025 [1,3]. The United States construction industry employed 11,896 thousand workers in 2023 [4], but a rapid decline is forthcoming, as the 2020 McKinsey report projected that by 2031, about 41% of the construction workforce will retire [5]. Also, construction programs will face more competition in student recruitment and retention as the number of college students is expected to decline by 15% beginning in 2026 [6]. Hence, there is an urgent need to shift construction methods toward more industrialized approaches and leverage digital information to enable the effective delivery of high-quality assets with a smaller but skilled and diverse workforce [5–7].

Therefore, this Work-in-Progress (WIP) paper presents a framework for an On-Screen Interactive Guide (OSIG) tool that employs "Learning by Doing" to promote practical, hands-on learning experiences with Building Information Modeling (BIM) software, as a pathway towards successfully educating and producing more skilled BIM workforces. Moreover, presenting this framework at the ASEE annual conference will help the authors gain feedback and input from other engineering education communities and establish partnerships with additional institutions and disciplines for the nationwide implementation of the OSIG in engineering software instruction and learning.

Examination of the Current State of BIM Instruction

Teaching and learning BIM software are both hard and time-consuming. The commonly used BIM modeling software, Autodesk Revit, has a complex user interface (UI) with numerous Tabs/Tools/Features, as shown in the UI sketch in Figure 1. Additional Tools/Features may also hide in the dropdown menus. Hence, at least four steps (and information pieces) are required for modeling a simple wall instance that includes:

1. Select the Tab: Architecture (a. which Tab has the potential Tool).
2. Select the Tool: Wall (b. which is the best option of Tool).
3. Determine the Features: Wall Type (c. where to input the parameter values).
4. Set the proper wall instance (d. dimensions and location).

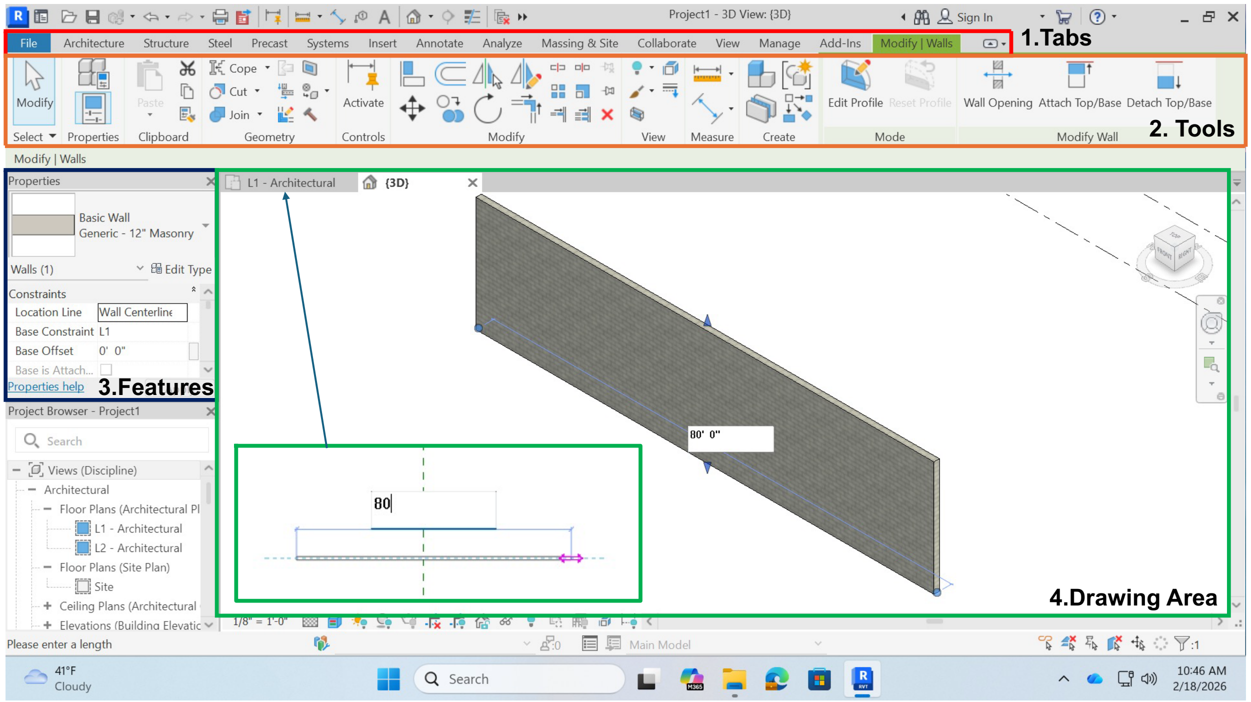

Figure 1 Autodesk Revit UI

As experienced BIM instructors, the authors observed that cognitive overload is common and easily encountered when learning this complex software in the computer laboratory classroom setting. Learners' attention frequently shifts between the BIM software UI, the step-by-step manual with text and annotations, and the instructor's demonstrations. For instance, when students follow the laboratory manual to achieve hands-on learning objectives, they need to find the four pieces of information (a to d) one by one in the instruction materials, then locate them in the software UI and input the specific parameter values. However, the following two unwanted situations always occurred, in which situation (i) relates to the task's complexity [8], and (ii) can increase the task's duration [9], as a result, cognitive overload frequently occurs in software labs.

(i) Students cannot find the corresponding Tool or parameters after reading the text and screen captures in the software manual or watching demonstrations, and then
(ii) Frequently request direct help from the instructor (if using a lab manual) or interrupt the instruction to repeat the previous procedures (if doing a live demonstration) [10].

Walkthrough of the OSIG Framework for BIM Instruction

Digital transformations and adoptions in business operations are increasingly successful when the On-Screen Interactive Guide (OSIG) is used during onboarding training [11]. Hence, this research aims to leverage the advantages of the OSIG to eliminate the confusion caused by the intricate BIM software UI in teaching and learning, such as directly pointing out the specific Tab/Tool/Feature and the parameter values on screen (see Figure 2). The proposed OSIG Framework for BIM Instruction is centered on addressing the following two fundamental questions for effective teaching and learning of BIM software skills:

(a) How to present software instructions as on-screen guides to learners – by using the universal OSIG player.
(b) How to create and modify on-screen guides by instructors – by using the universal OSIG editor.

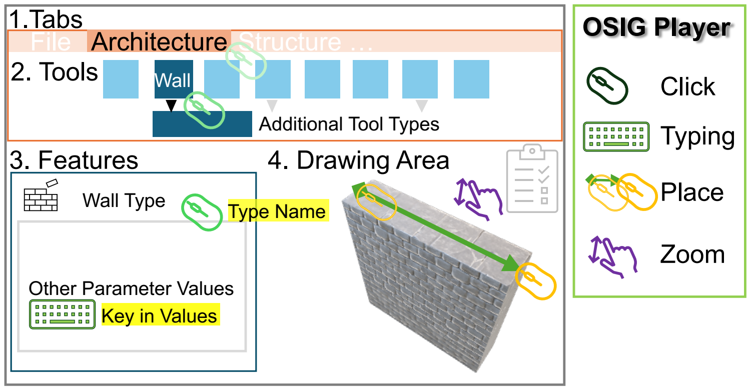

Figure 2 Sketch of On-Screen Interactive Guide (OSIG) Player

Like the regular modeling steps 1 to 4 shown in Figure 1, the OSIG player will step-by-step display on-screen guides over the BIM software UI with visual aids for mouse clicks and keyboard inputs, selecting from dropdown menus (with option names), moving (with start and end points), zooming, and typing (with key-in values). The learners are supposed to follow the on-screen guides and corresponding audio instructions to perform actions such as clicking, typing, moving, and zooming. The workflow of the proposed OSIG player is shown on the left of Figure 2. After completing each step, the corresponding audio effect will also help to create interest and engage learners in the software learning process [12].

Like the block-based programming, the illustration of the OSIG script is shown in Figure 3. The OSIG player decodes and executes the action blocks from left to right and from top to bottom to deliver on-screen instructions. In reverse, to create an OSIG script, an instructor selects blocks of Tabs/Tools/Features from the library (setting parameter values if applicable) and orders them in the desired sequence. This research considers saving the OSIG scripts as English-like syntax, where the tabs, tools, and feature names and values or numbers can be easily verified. It also enables the use of generative AI to generate the OSIG script for the given design criteria, which will be discussed later.

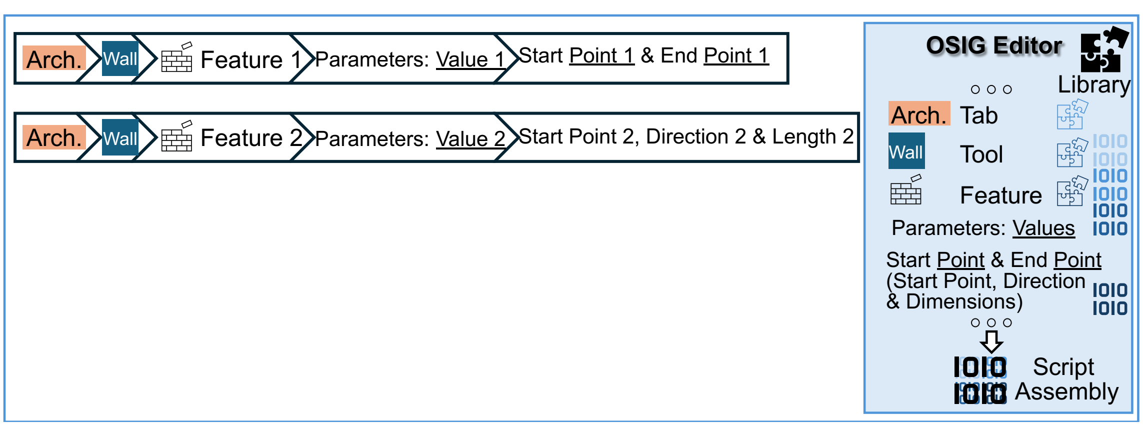

Figure 3 Sketch of OSIG Editor and Script

In the implementation, there are two ways to decode the OSIG script to *Revit's* Tabs/Tools/Features and their on-screen coordinates: (a) using a dictionary to interpret Tabs/Tools/Features' names to on-screen coordinates for these frequently used Tabs/Tools/Features with some common screen resolutions, like 1080p and 2k. (b) using a dictionary to interpret Tabs/Tools/Features' names to icons (images), then locating them on any-sized screens via pattern recognition [13]. This approach is also suitable for the UI layout changes after a software version upgrade. Hence, this research will develop and continually enrich the Tab/Tool/Feature library and the associated OSIG script datasets to cover the most common BIM software functions suggested by AEC professionals.

Discussion of Comparative Experiment

Common BIM skills include 13 topics: creating/modifying Walls, Doors & Windows, Floors, Roofs, Ceilings, Stairs, Structural, Rooms, Views, Tools, Dimensions, Sheets, and Schedules. To understand the effects of the on-screen instructions on students in learning those BIM software skills, students can be randomly assigned to two groups: a software manual-based learning group and an OSIG-based learning group for each topic to conduct comparative experiments. To ensure the experiments do not affect students' learning in those 13 topics, a follow-up in-class demonstration-based learning will be conducted if needed.

To check the software learner's skills learning progress, test their skills retention level, and assess their cognitive load (CL), an Intelligent Learning Progress Checker (ILPC) will be designed to run simultaneously with the OSIG player. The ILPC will collect the data of the learner's actual on-screen actions of mouse clicking and keyboard typing, task durations, and screenshots with the mouse cursor at each step. Then, for performance checking, the ILPC can compare the learner's actual on-screen actions with script-stated ones. Moreover, the ILPC can also collect students' objective feedback (e.g., pre-test knowledge level and post-test skills retention level) and subjective feedback (e.g., learners' CL self-rating scales [14], post-study, and test surveys).

For data analysis, students' CL self-rating scales and task durations for each step will be used for statistical tests on the following Hypotheses: when achieving the same learning outcome (i.e., mastering the same software functions and skills), the software manual-based learning group has a larger cognitive load; and the OSIG-based learning group has the lowest cognitive load and costs less time. Hence, the t-test is the method for comparing group means of the students' CL self-rating scales and their task durations. Moreover, the ILPC post-study survey, conducted after each topic session, will collect individual students' feedback on the OSIG player and the laboratory manuals.

Future Work

As shown in Figure 2, OSIG Scripts have detailed breakdown steps to follow, a learner requires zero effort in thinking/deciding where to start modeling or which is the best/alternative Revit Tool to use. As a result, learners may have a low software skill retention level. Hence, an advanced interactive approach of adaptive learning [15] may be adopted. It only gives the design criteria first and allows learners to explore and locate the correct Tabs/Tools/Features to achieve the design goal. As shown in Figure 4, the OSIG*AI* will highlight the on-screen instructions if a learner gets stuck at a step. If the learner performs an incorrect action, the OSIG*AI* will notice an error and undo the last action, but will wait for the learner to take the correct action first. The Checker (ILPC) can check the learner's actions with the Script to progress the learning. Moreover, a text/code generative AI model will be designed to generate an OSIG Script from the given design criteria, providing personalized learning materials for each learner.

Moreover, cognitive load (CL) is also influenced by learning environment and situational conditions, as well as learner characteristics and skills [16]. An optimized CL level is desired because high cognitive load levels and too low levels can lead to decreased performance and increased errors [17,18]. Effective learning occurs when instructional materials manage this cognitive load appropriately by minimizing extraneous cognitive load (e.g., irrelevant information) and maximizing germane cognitive load (e.g., meaningful connections) [19,20]. Design thinking (DT) [21,22] is a problem-solving methodology that prioritizes empathy, creativity, and iterative processes. Integrating design thinking with instructional design enables learner-centered solutions that emphasize learner needs and iterative prototyping. Hence, the generative AI-powered OSIG*AI* should emphasize DT and an optimized CL. The AI-generated personalized learning BIM software instructions will help learners face the unknown by slicing the challenge into smaller parts that they can tackle individually and link with their prior knowledge. In addition, the content and pace should be adjusted based on the learner's performance and preferences for adaptive learning [15].

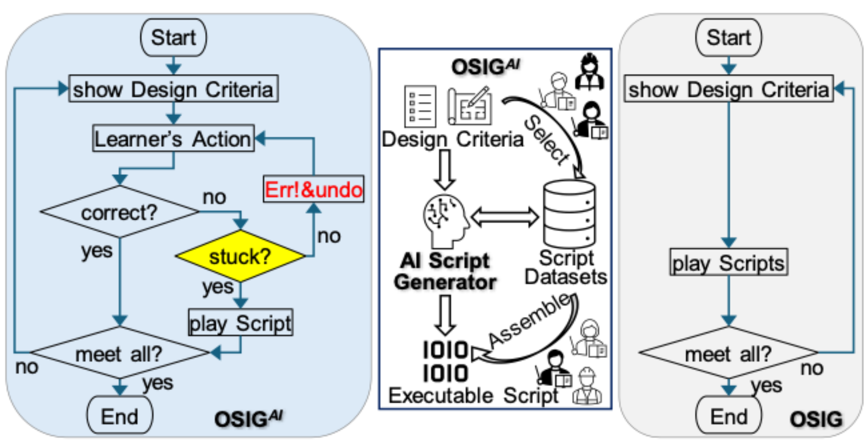

Figure 4 Workflows of Proposed OSIG and OSIG^{AI} Learning Approaches

Conclusion

Using the On-Screen Interactive Guide (OSIG) Tool to Promote Practical Hands-on Learning Experiences on Building Information Modeling is transformative in three major ways. First, how BIM Revit software functions and skills are taught and learned is novel and transformative, as current learning approaches are time-inefficient and low-engagement. Therefore, specifically developing OSIG to reduce instructors' stress and anxiety in teaching and reduce students' cognitive overload in learning will add significant value to application software learning in formal and informal settings. Second, collecting and analyzing students' feedback (e.g., knowledge level in pre-test, performance data of completing each study and test steps, and the skills retaining level in post-test) and subjective feedback (e.g., Cognitive Load (CL) self-rating scales at each study and test steps, and post-study and -test surveys) can have cross-validation and better and deep understand the characteristics of each learning groups, as the results, the generative AI can create the best and personalized OSIG^{AI} scripts for any individual learner. Third, the theoretical framing uses *Learning by Doing* as a foundational approach, and the integration of CL theory within a *Design Thinking* framework indeed represents a novel and transformative perspective. It puts learners at the center of the challenge, framing their critical thinking skills for problem-solving in the context of the digitalization of the built environment.

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