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Work In Progress - Empowering Undergraduates with Virtual Labs: Interactive Learning of Core Engineering Principles using Ansys Discovery

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WIP: Empowering Undergraduates with Virtual Labs – Interactive Learning of Core Engineering Principles using Ansys Discovery

Introduction

Modern engineering software with built-in instructional tools and guided overlays provides a powerful new avenue for teaching core concepts to early-year engineering students [1], [2]. Embedding context-sensitive help, step-by-step guidance, and interactive content directly within the simulation environment lowers the barrier to entry for novices [3]. Instead of pairing textbook theory with separate software tutorials, students can learn fundamental principles while actively engaging with the software environment. This seamless blend of simulation, visualization, and instruction fosters intuitive understanding of concepts, accelerates skill development, and builds student confidence in applying computational tools to real engineering problems [1], [4]. It also helps students develop computational thinking skills by guiding them through logical steps in problem-solving within the software [2].

In this paper, we introduce two integrated instructional enhancements in Ansys Discovery aimed at bridging the gap between theoretical learning and hands-on simulation for undergraduate engineering education. First, a Python-based Extension Builder virtual lab has been developed, focusing on a static I-beam bending analysis as an interactive laboratory exercise [5], [6]. This custom "add-in" guides students through the simulation of an I-beam under load, reinforcing concepts like displacement, stress, strain, and beam theory in real time. Second, we describe new instructional overlay tours built into Ansys Discovery's interface, which provide on-screen conceptual explanations during simulations. These overlays answer the "why" behind simulation results (fundamental physics and principles) rather than just the "how-to" of using the software. By combining a guided virtual lab with conceptual overlay pop-ups, the approach aims to bridge analytical theory with real-time simulation and reduce the learning curve for students [7], [8], [3]. This work was developed within the context of the Ansys Academic Program, which supports institutions and educators by providing access to industry-standard simulation tools for teaching and curriculum development.

Background and Motivation

Traditional engineering education often requires students to connect abstract textbook theory with practical software tools on their own, which can be challenging for novices. Early-year students with minimal exposure to finite element analysis (FEA) may feel overwhelmed when asked to use professional simulation software without sufficient guidance [9], [1]. This disconnect can impede learning, as students spend more time struggling with software mechanics than understanding the underlying engineering concepts. Embedding guided instructional content into the software itself is a promising strategy to reduce cognitive load and keep the focus on core principles [10], [3], [11].

Educational learning theories advocate that deep learning occurs through active construction of knowledge in a meaningful context. In other words, students learn best by doing – by interacting with the material and constructing their understanding through hands-on activities in a supportive environment. Creating tangible learning experiences (such as virtual experiments) within a structured environment allows personal, meaningful understandings to form. The emphasis is on the learning process (the interaction between student and environment) rather than just the end result or correct answer. In the context of mechanics education, a virtual lab inside a simulation tool can provide this rich interactive environment where theory directly meets practice [12], [2], [4].

Several prior efforts in engineering education have attempted to use simulations and virtual labs to enhance learning. However, those often rely on external modules or separate instructions that students must follow alongside software, which can still be disjointed. In contrast, the approach presented here tightly integrates the instructional guidance into the simulation software interface itself. By doing so, the barriers to learning are further lowered – students receive help at the moment they need it, in the same window where they apply it. This approach aligns with constructivist pedagogy, where scaffolding is provided within the learner's zone of proximal development [9], [11]. The I-beam virtual lab extension and the interactive conceptual overlays in Ansys Discovery were designed with this in mind: to create an active learning environment within the simulation tool, allowing students to seamlessly move from theory to application. The ultimate motivation is to help students build intuition for core engineering principles (like beam bending behavior) through interactive visualization, thereby strengthening the connection between theoretical formulas and real-world behavior [10], [13], [4].

Methodology

In this work, two methods of embedding instructional content into Ansys Discovery software are implemented and tested: (1) a custom Python-based Extension Builder virtual lab for a static I-beam analysis, and (2) new interactive instructional overlays within the software's user interface. Both are aimed at first- and second-year engineering students with little or no prior FEA experience. Below, we describe the design and features of each approach.

Virtual Lab Extension: I-Beam Bending Simulation

The first approach is an interactive virtual lab built using Ansys Discovery's Extension Builder (a Python scripting framework for custom add-ins). We developed an extension that introduces students to a static structural analysis of an I-beam, a fundamental topic in mechanics of materials. This extension functions as a guided lab exercise integrated into Discovery's interface, complete with custom buttons, prompts, and automated actions to walk students through the simulation workflow.

Implementation: The I-beam lab extension was created with low-code Python scripts using the Extension Builder tool. Once installed, it appears as a new tab or panel in the Discovery interface, offering a structured sequence of steps for the student. The extension provides learning overlays at each step, meaning the software displays instructions or tips relevant to the current task (for example, when the student needs to select a face for applying a load, a hint box might explain how to make selections and why the load is applied on that face). The interface includes intuitive buttons and scripted actions that perform or check certain tasks, so students can focus on understanding the setup rather than wrestling with software commands.

Guided Workflow: In a typical usage of the I-beam virtual lab, students proceed through a series of steps that mirror a real engineering problem setup, as shown in Figure 1.

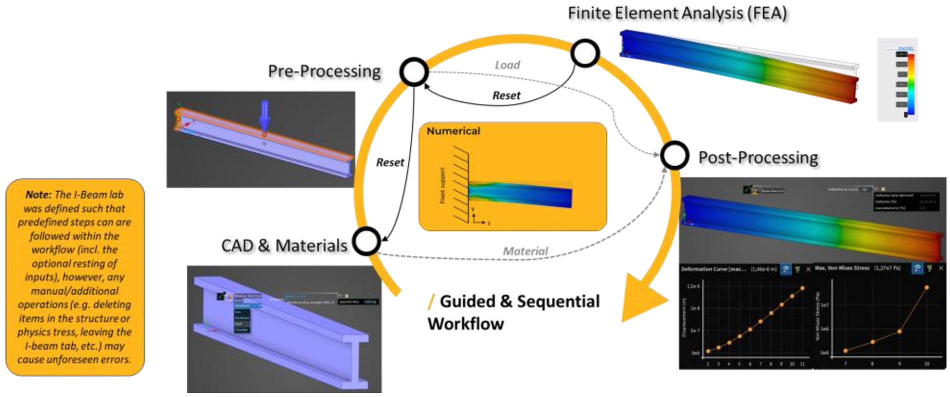

Figure 1: Guided and sequential workflow for I-Beam Virtual Lab

Geometry Exploration: The lab loads or generates a standard I-beam geometry for analysis. Students can inspect the beam's dimensions and are prompted to consider how its cross-section (I-shape) contributes to strength. The extension might overlay a brief explanation of cross-sectional moment of inertia and why I-beams are efficient for bending loads.
Material Selection: Students assign a material (e.g., structural steel) to the beam through the extension's interface. The tool can provide a pop-up note about material properties (Young's modulus, yield strength) and how these affect deflection and stress. Figure 2 shows the geometry creation process (CAD) and material assignment.

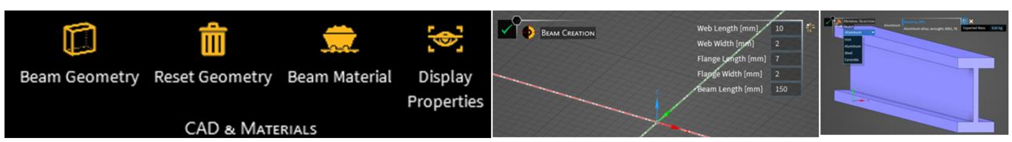

Figure 2: CAD model and material assignment

Boundary Conditions: The extension guides the student to apply support and loads. For example, it may instruct the student to fix one end of the beam (simulating a cantilever or simply supported end) and apply a force on the other end or distributed load on the top flange. The lab's script can automatically apply these boundary conditions once the student confirms the selection, ensuring the setup is correct. Along with the "how", the on-screen text might explain why a particular support condition is used (e.g., "the left end is fixed to mimic a wall mount, causing a bending moment along the beam"). Figure 3 shows the Pre-processing steps and preparing the problem for solution.

Figure 3: Pre-Processing & FEA (Solving)

Solve and Visualize: With one click in the extension panel, the simulation runs. The virtual lab then automatically displays the results of interest, such as the von -mises stress distribution and deflected shape of the beam, as shown in Figure 4. The extension can customize the result view – for instance, highlighting the maximum stress location and listing that value, or showing a comparison of simulation deflection vs. an analytical Euler–Bernoulli beam theory prediction.

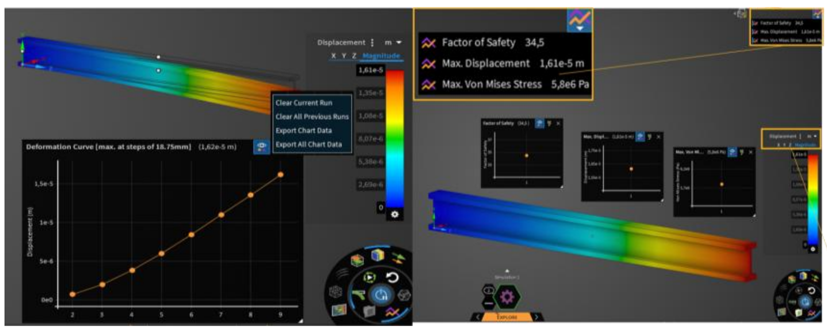

Figure 4: Post-processing: simulation results for different state variables such as displacement, von-mises stress, and factor of safety.

Interactive Exploration: Students are encouraged to interact with the results. The extension might allow them to adjust the load magnitude or beam length and re-run the simulation to see how the stress and deflection change, as shown in Figure 5. This interactivity reinforces learning by connecting cause and effect in real time.

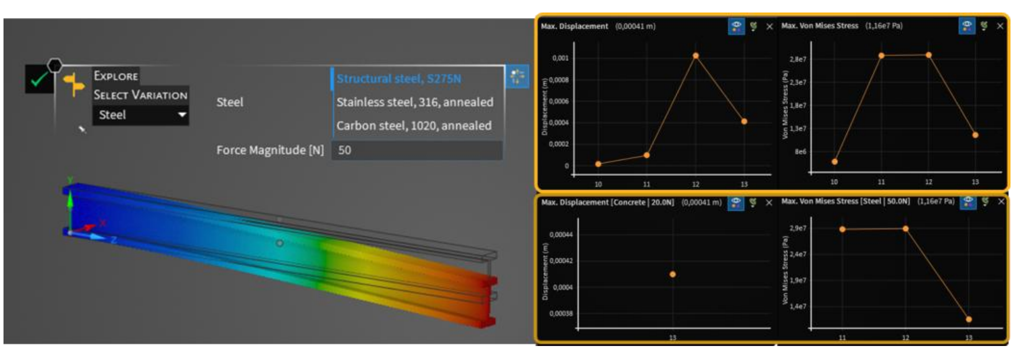

Figure 5: Exploring the effect of materials and forces on the state variables

Educational Features: The I-beam virtual lab extension is designed to keep students actively engaged and supported throughout the exercise. Key features include:
Step-by-Step Prompts: At each stage (geometry, material, boundary conditions, solve), the extension provides written prompts or checklists in the interface. This scaffolded guidance means students always know what to do next and why it matters, reducing frustration and ensuring no critical steps are missed.

Embedded Explanations: Contextual help boxes are integrated to explain engineering concepts on-the-fly. For example, when viewing the stress results, a small overlay can define von-Mises stress and why it's relevant for failure theories, or recall the formula for maximum deflection $v_{max} = \frac{-qL^4}{8EI_{xx}}$ to connect the visual results with theory, where q is the uniform load, L is the beam length, E is Young's modulus, and I_{xx} is the area moment of inertia about the neutral axis.
Visualization of Theory vs. Simulation: The lab encourages comparison between analytical calculations and FEA results, as shown in Figure 6. It might include an automated calculation of expected maximum deflection using beam formulas for the given load, then prompting students to compare these values with the simulation output. By reinforcing analytical comparisons, students see that simulation is not a "black box" but rather another way to arrive at results that should coincide with theory (within reasonable error).

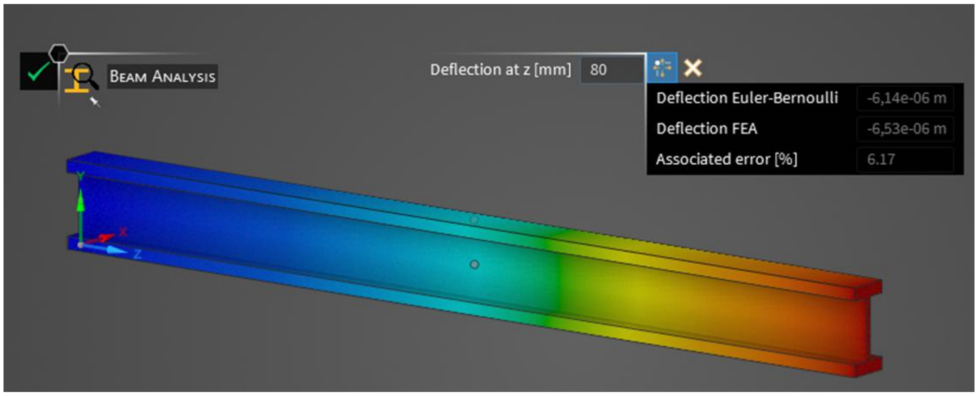

Figure 6: Comparing Analytical versus FEA results comparison for deformation

Instructor Customizability: Because the lab is built via Python scripting, instructors can easily modify or extend it. They could change the scenario (e.g., analyze a different beam cross-section or a different loading condition) or insert additional instructional steps (such as a quiz question: "Where is the neutral axis located and what is the stress there?"). This flexibility allows rapid tailoring of the learning path to fit specific course objectives or student needs.
Overall, the virtual lab extension enables students to seamlessly transition from theoretical concepts (stress, strain, beam deflection formulas) to hands-on simulation in one continuous learning experience. Even students with no prior FEA software exposure were able to complete the I-beam lab with minimal external help, thanks to the in-software guidance. In essence, the Extension Builder lab transforms a traditional paper-and-pencil exercise into an interactive simulation experiment, where students can visualize internal stresses and deformations, actively reinforcing their understanding of core mechanics principles.

Interactive Instructional Overlays in Discovery

The second approach involves the use of instructional overlay tours in Ansys Discovery – an emerging feature of the software originally developed for onboarding and help tutorials. In Discovery, Interactive Tours are guided sequences that highlight parts of the interface and show explanatory text to help users learn software operations. We have expanded this concept to create overlays that teach fundamental engineering concepts in context, effectively turning passive help bubbles into micro-lesson pop-ups inside the simulation.

Overlay Design: The new instructional overlays are triggered as part of structured example simulations (which students can launch from a “Learning Tours” menu). When an overlay tour is activated, the software will perform a simple simulation (such as applying a load to a beam or pressure to a vessel) step-by-step, and at each step an overlay window appears with a short explanation or question. These overlays focus on the conceptual understanding – the “why” – rather than just telling the user which button to click. For instance, instead of saying “Click here to show the stress plot,” an overlay might explain that the bending moment is largest at the fixed support, causing the highest tensile stress there, linking back to theory. The student can then proceed, having gained insight into the reason behind the result.

Content of Overlays: The overlays cover key principles and definitions that relate to the simulation at hand. In the case of a I-beam virtual lab, the overlays would introduce or reinforce concepts such as stress vs. strain, elastic deformation, factor of safety, beam boundary conditions, and interpretation of simulation results. They often use simple diagrams or highlight portions of the model on screen (e.g., an arrow pointing to the red region of high stress with an explanation of stress concentration). The tone is kept accessible and explanatory, so that as students follow the interactive tour, their knowledge is scaffolded by these bite-sized lessons embedded in the workflow.

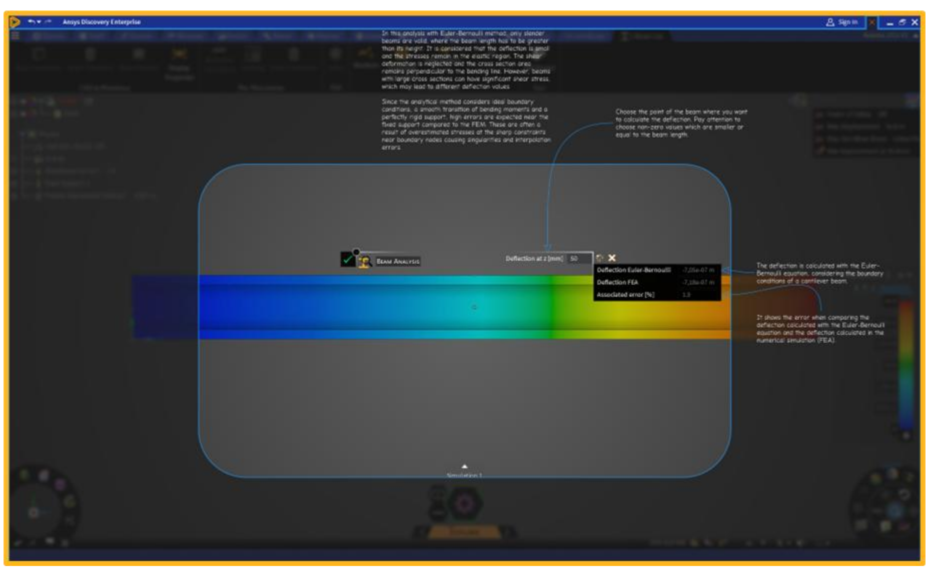

Figure 7: Educational overlay to support learning

Some characteristics and benefits of the overlay approach are:

- Demystifying the “Black Box”: Simulation software can feel like a black box to students – they input numbers and get colorful plots but might not grasp what happens in between. The overlays explicitly address this by explaining what the software is doing at each step (for example, “The solver is constructing a mesh of the geometry – breaking the beam into many small elements. This is how the computer approximates the equations of elasticity over the complex shape.”). This running commentary makes the simulation process transparent and educational.
- Concept Emphasis Over Tool Instruction: While traditional tutorials focus on software usage (click this, enter that), these conceptual overlays focus on engineering reasoning. They presume the student is simultaneously learning the tool by doing but ensure that the reason behind each step and result is clear.
- Option for Self-Paced Learning: The interactive overlays are optional and can be toggled. Early-year students can benefit from going through the full guided tour with overlays explaining every detail. In contrast, more advanced students or professionals (or even the same student on a second run) might skip certain overlays or disable the tour once they grasp the concepts. Thus, the system can serve as a reference or refresher – if a student forgets what a term means, they can quickly trigger an overlay on that topic without leaving the software to search in a textbook.
- Integration with Simple Simulations: The overlays are currently implemented with relatively simple example simulations to keep focus on fundamentals. For instance, the beam example might be a cantilever beam with a point load – straightforward enough that the physics can be explained succinctly. More complex scenarios (like multiple load cases or dynamic simulations) can be tackled by chaining overlay tours or by providing layered tours that build up complexity gradually.

In summary, the instructional overlays act as an in-situ tutor, answering “Why does this happen?” at the exact moment the student encounters a new result or concept in the simulation. This just-in-time conceptual guidance reinforces classroom theory. Early feedback indicated that students found these overlays extremely helpful in clarifying confusing points. The overlays have been imbedded into the I-beam virtual lab to provide students with the fundamental concepts and instructions throughout the process and help them understand what they are doing.

Results and Discussion

Based on the instructional design and embedded guidance strategy used in the I-beam virtual lab extension and the conceptual overlay tours, we anticipate several key impacts on student learning.

First, the virtual lab's step-by-step scaffolding, visual simulation outputs, and real-time interaction are designed to reduce cognitive load, especially for students with limited experience in simulation tools. By integrating analytical comparisons within the workflow, the lab promotes conceptual understanding of stress, strain, and beam theory through direct visualization. This approach is expected to enhance students’ ability to connect theoretical principles with simulation results, thereby improving comprehension and retention.

Similarly, the instructional overlay tours are structured to provide just-in-time explanations of fundamental concepts within the context of simulation tasks. By emphasizing the "why" behind simulation outcomes rather than simply guiding software usage, these overlays serve as conceptual reinforcements that adapt to the learner's pace. We expect this will help demystify simulation processes for beginners while offering flexibility for more advanced users.
From an instructional perspective, both tools are designed to streamline classroom implementation. The embedded guidance reduces the need for extensive instructor-led troubleshooting, allowing faculty to focus on deeper conceptual discussions and personalized support. This model of integrated learning support is intended to foster student autonomy while reinforcing key engineering principles through active engagement.
As future iterations are deployed and evaluated, we anticipate confirming these projected benefits through classroom assessments and structured student feedback.

A primary limitation of this work is the absence of formal, quantitative student assessment data at the time of submission. While the instructional tools described in this paper were designed using established pedagogical principles and piloted in instructional settings, systematic student feedback, learning outcome measurements, and comparative studies have not yet been completed. As a result, the educational impact discussed in this paper is inferred from the instructional methodology and observed classroom implementation rather than validated through controlled assessment. Future work will focus on collecting structured student and instructor feedback, including surveys, concept inventories, and performance comparisons against traditional instructional approaches. We also seek to collaborate with faculty partners across institutions to deploy these virtual labs in diverse curricular contexts and evaluate their effectiveness at scale. Such collaborations will enable rigorous assessment of learning gains, usability, and long-term student engagement, strengthening the evidence base for simulation-driven instructional approaches in engineering education.

Conclusion

This study demonstrates how the synergy of a low-code Python-powered Extension Builder lab and on-screen instructional overlays in Ansys Discovery can transform the learning experience for fundamental engineering topics. By tightly integrating instructional content with simulation software, we created a virtual lab environment that allows early-career engineering students to learn by doing – bridging the gap between theoretical formulas and real-world simulation in a seamless, interactive manner. Students using the I-beam virtual lab could visualize stress and deformation as they learned about beam bending theory, resulting in improved intuition and confidence in applying computational tools. The contextual overlays further enriched the experience by explaining the underlying concepts and answering "why" questions at exactly the right moments, thereby demystifying the simulation process for newcomers.

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