Development of Interactive Virtual Labs for Statics by Utilizing Artificial Intelligence Chatbots

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Abstract

To improve student understanding of course content and improve student retention in the Engineering Mechanics: Statics course, we have revisited the current format of the discussion sessions we offer at Oklahoma State University. A past study explored, employed, and evaluated hands-on labs for these sessions. However, these activities are no longer used in the discussion sessions and the practicality of reimplementing these demonstrations has proved difficult. Therefore, it was decided to explore introducing virtual labs into the discussion sessions.

While there is extensive existing literature regarding the effectiveness of virtual labs in engineering education, there is a significant gap in how these labs are developed. To help close this gap and due to limited coding knowledge by the faculty who instructed the course, we propose the use of generative artificial intelligence chatbots (GenAI chatbots) to develop virtual labs. In our use case, we explored vibe coding, which uses AI chatbots to provide code based on written language prompts, and found it as a viable option for creating virtual labs. The successes, issues, and resolutions related to using AI chatbots and vibe coding for the purpose of creating these virtual labs is discussed. Additionally, the potential security vulnerabilities regarding vibe coding are explored and a proposed mitigation strategy to reduce risk is provided.

Introduction

Statics is a fundamental course for engineering students in their undergraduate curriculum, not only for the foundation it builds for future success in engineering courses but also for its role in retaining students. Ultimately, if students are unsuccessful in Statics, they will not be able to progress in their engineering curriculum. This increase in pressure on the faculty member teaching the Statics course can lead them to explore, employ, and evaluate alternative means of learning to increase student comprehension and retention of course content. One recent exploration by the faculty at Oklahoma State University, led to the discovery of virtual labs due to their increased flexibility, accessibility, and cost efficiency in engineering courses [1]. Due to lack of experience with coding, we explored the recent popularity in vibe coding to develop these virtual labs.

Vibe coding entails utilizing generative artificial intelligence (GenAI), such as ChatGPT, Claude, and Gemini, to develop code. The user provides only the feel of what they want to be achieved by the code, the “vibe,” and instructs the AI chatbot to produce the code by using written language prompts. Artificial intelligence is defined as the “capability of computer systems or algorithms to imitate intelligent human behavior” and generative AI can be defined as a type of AI technology that generates content such as text, images, audio, and video. A chatbot is a computer program that uses a large language model (LLM) to simulate a conversation with human users, typically through text [2]. We will use the terms GenAI and AI chatbot interchangeably using the definition that a generative AI chatbot is a type of artificial intelligence system designed to engage in human-like conversations by generating text-based responses dynamically rather than relying on pre-programmed replies.

During the creation of these virtual labs, we also considered potential security vulnerabilities associated with vibe coding and implemented an approach to mitigate risk.

Overview of the Statics Course at Oklahoma State University

Engineering Mechanics: Statics is one of the first engineering courses that students enroll in at Oklahoma State University and most students enrolled in this course are in the first or second year of their curriculum. The course is instructed primarily through a systematic approach and presents most of the course content through in-person lectures which take place in three 50-minute lectures a week and one 50-minute discussion session instructed by a teaching assistant (TA). In 2014, discussion labs were explored to help reinforce topics presented in the theory sessions and improve student understanding in the Statics course. The discussion labs were employed in the course with three hands-on lab exercises that reinforced topics presented in the theory sessions. The labs covered the topics of particle equilibrium, truss structures, and static friction. Evaluation on the use of the lab exercises concluded that there was a slight increase in averages on homework and exam grades [3].

Since 2014, the course has been taught by different instructors and as a result, the hands-on activities disappeared from the discussion labs. The current format of the discussion labs has been transformed into discussion sessions which utilize teaching assistants to work out one or two example problems by hand while the students copy the solution alongside the TA. After the example problem, students are given a quiz to work independently. With continued low-test scores, low retention, feedback from students that the discussion sessions are similar to the lectures, and with the latest change of instructors in the course, it was decided to explore alternative means of learning for these discussion sessions to enhance student mastery of content and retention.

Rationale for Adopting Virtual Labs

When considering if the hands-on learning exercises could be reimplemented into the course, we were presented with the challenge of how we could facilitate these hands-on activities with the large number of students who are enrolled in Statics. In 2014, the enrollment of students was approximately 200 to 350 each semester [3]. With enrollment continually growing, there are now approximately 300-400 students each semester and between 12 to 18 individual discussion sessions. Considering the large number of discussion sessions which are held in different rooms on campus, at various times throughout the day, and taught by different teaching assistants, the practicality of implementing hands-on experiments in the discussion labs appeared problematic. This led to the exploration of virtual labs.

To understand whether virtual labs should be used, we performed a search of existing literature using Elsevier Scopus and Google Scholar to collect articles using key words such as “virtual lab*,” “higher education,” “undergraduate,” “engineering,” effective*,” among several other similar variations of these words. We also limited our search to articles in English and between the years of 2015 to 2025 to include the pre- and post-COVID 19 years when remote learning gained a notable increase of interest by educators. A systematic literature review [4] and a meta-analysis [5] on virtual labs as they relate to engineering courses was also reviewed.

It was found in our review of existing literature that virtual labs demonstrated effectiveness in supporting student learning, confidence, and conceptual understanding. Studies consistently report that students using virtual laboratories achieve learning outcomes comparable to those of students in face-to-face laboratory settings, with no significant differences in knowledge gains [1]. Aurich et. al [6] used virtual labs in an undergraduate fluid mechanics course and found that students showed high acceptance of using digital tools in higher education, a medium increase of students' general knowledge, highly positive effect regarding students' learning motivation, active participation, and communication, and highly positive evaluations. Li and Liang's [5] meta-analysis concluded that the use of virtual laboratories in engineering education can significantly enhance teaching effectiveness and therefore the continued development and utilization of virtual laboratories are essential.

From an institutional standpoint, virtual labs also reduce financial and logistical burdens by minimizing the need for physical infrastructure, costly equipment, and extensive preparation time, while allowing virtual models to be reused and modified across multiple experiments. The virtual labs were also seen as an economically viable solution for our program as we face limited resources, increasing enrollments, and restricted access to physical lab space [7].

In addition to our understanding that virtual labs are an effective learning tool and have institutional benefits, we envisioned that these virtual labs would provide students with a more interactive approach to learning core concepts in a format that contrasted with the current approach. The virtual labs would not require set-up time for the TAs, and the current format of the discussion sections and rooms could be kept the same. This also resulted in no disruption for administration. Additionally, students are already required to purchase a laptop as an engineering student within the College of Engineering, Architecture, and Technology and the implementation of using virtual labs would not require any additional technology expenses for the student.

Therefore, it was determined that there is overwhelming evidence suggesting that virtual labs should be implemented into the Statics course, but despite the extensive literature on virtual labs we identified a significant gap in the current literature regarding how these virtual labs are developed. Although there are existing software and simulation platforms that exist, the instructor does not have control over the material that is produced and cannot easily revise the virtual labs to fit their specific needs and teaching style. Therefore, it is important for instructors to understand how to develop their own virtual labs.

Rationale for Adopting Vibe Coding for Virtual Lab Development

The lack of information on how to create virtual labs presented our largest challenge. How is the coding for virtual labs completed? Who provides the code? How are revisions and changes completed? The limited knowledge of coding that would allow for the development of an interactive virtual lab was a major factor that would have previously prohibited us from considering them.

However, in February 2025 Andrej Karpathy introduced the world to the term "vibe coding" through his post on X (formerly Twitter). He described in his post that vibe coding is "where you fully give in to the vibes, embrace exponentials, and forget that the code even exists [8]." He discusses that since large language models (LLMs) used to develop AI Chatbots (such as ChatGPT, Gemini, and Claude) have become so good, we can utilize them to provide the code and as the human in the loop we really only have to "see stuff, say stuff, run stuff, and copy paste stuff" for it to mostly work [8].

In our development of virtual labs, we utilized Gemini 3 Pro Preview, which is a GenAI developed by Google. We used Gemini within Google AI Studio due to its user friendliness and its ability to use more advanced models for free. Our selection of using Gemini was based primarily on user preference and familiarity with this chatbot, but ChatGPT was explored as a potential chatbot. Perhaps due to unfamiliarity with the prompting of ChatGPT, we found that we did not have as much success in getting the desired outcome as quickly as we did with Gemini.

We also determined that using cascading style sheets (CSS), JavaScript (JS), Python, and HTML languages would suffice for our virtual labs. The origin of initially trying CSS, JS, and HTML came from a YouTube video in which the content creator produced a Pokémon Pokédex using these coding languages. Khonde et al. [9] provides how CSS, JS, and HTML are powerful enough to build a smart virtual chatbot assistant and demonstrates a good starting point for our virtual lab development. HTML is used to structure the document, CSS provides the aesthetics, JavaScript provided the interactive elements, and Python was used for the more complex 3-dimensional examples where JavaScript proved to be insufficient. Since we were unfamiliar with these coding languages, we only used the vibe coding approach to use the various coding languages that ultimately developed a single HTML file that can be downloaded by students and opened in any internet browser. While AI can assist in the content creation, concerns remained regarding code security, reliability, and ethical implementation [10].

Mitigating Potential Security Vulnerabilities

We recognize there are potential security vulnerabilities involved with using GenAI to produce code that we expect students to download on their personal computers. Therefore, it is imperative that we mitigate risk as much as possible. We will discuss our considerations regarding potential security vulnerabilities associated with our virtual lab development for clarity in our review, but for our specific use, the code produced by Gemini did not pose significant security vulnerabilities and the few that may occur have been easily mitigated through a set of system instructions within Gemini.

Maes suggests that security issues with vibe coding come from three primary factors, optimization bias, blind spots, and dependency issues [11]. Optimization bias may occur due to the GenAI tools prioritizing the creation of the code over making it secure, blind spots for the GenAI tools may emerge when developing the code since GenAI tools do not tend to think like an attacker leading to it missing common vulnerability patterns, and dependency issues may occur when GenAI produces code that calls external libraries and packages [11].

In order to mitigate risk associated with Maes' three primary factors we explored the option of using the system instruction feature of Gemini in Google AI Studio. The system instructions can be used for the tone and style of the output from Gemini. To prevent optimization bias, we gave specific instructions regarding Gemini's role as an Engineering Statics Professor and Senior Security Engineer to emphasis the importance of accurate concepts and security in the code. Regarding potential blind spots in the form of vulnerabilities, we reviewed a few popular vulnerabilities which included structured query language (SQL) injection and embedding application programming interface (API) into the code. Since we will use JS as our coding language, there is no backend database where SQL injection would be a threat, and we are using the free version of Gemini so that we do not have an API key.

While it is unlikely for us to have dependents in the developed code, dependency issues can be easily mitigated in the system instructions. Dependency issues occur when GenAI produces code that calls external libraries and packages. The weakness is created when a potential attacker creates a package with the same name as the made-up external library or package and gets users to unknowingly download malicious code [12]. Additionally, the regulations relating to the Family Educational Rights and Privacy Act (FERPA) were also a consideration for us to ensure that the code produced does not store any personal data from our students.

To provide one last layer of protection against vulnerabilities, we included a final set of instructions to require Gemini to review the final code and report any additional risks. The following is the full set of system instructions we used to help mitigate potential security vulnerabilities:

> "You are an Engineering Statics Professor and a Senior Security Engineer. If a user request has the potential for security risks, stop and warn them before proceeding. When generating code, you must adhere to these non-negotiable security standards:
>
> 1. Zero External Dependencies: Do not link to external libraries or programs. The file must be fully functional offline.
> 2. Data Privacy: Use sessionStorage instead of localStorage. Ensure when final file is used, that work and data is automatically wiped when the browser is closed protecting privacy on shared computers.
>
> If a user request violates these rules, stop and warn them before proceeding. Scan final code for any potential security vulnerabilities and list any remaining security risks. If no identifiable risks remain, state this when providing the code."

Although we have attempted to reduce security vulnerabilities through the use of system instructions, due to the complexity of providing quality assurance and mitigating security risks associated with vibe coding and our lack of experience with coding languages, the safest and most reliable option is for the code to be thoroughly reviewed by a person familiar with coding and cybersecurity. Another potential option, although less reliable, is to utilize specialized AI to review the code, such as GitHub Copilot, SonarQube, CodeRabbit, and DeepCode [13].

Discussion on Virtual Lab Development

The curriculum development of our virtual lab activities was based on the behaviorist approach. This approach is common in engineering education and provides an efficient way to teach skills and introductory content that might be needed for future complex and higher-order thinking. The framework used to develop the virtual labs and the accompanying activities was based on the Hunter model, which is often considered the primary method of behaviorist lesson planning that was developed by Madeline Hunter in her book *Teach More – Faster* in 1967 [14]. The

Hunter model lists seven specific, sequential elements of the lesson plan which include Anticipatory set, Objective and purpose, Input/direct Instruction, Modeling, Checking for understanding, Guided practice, and Independent practice [14].

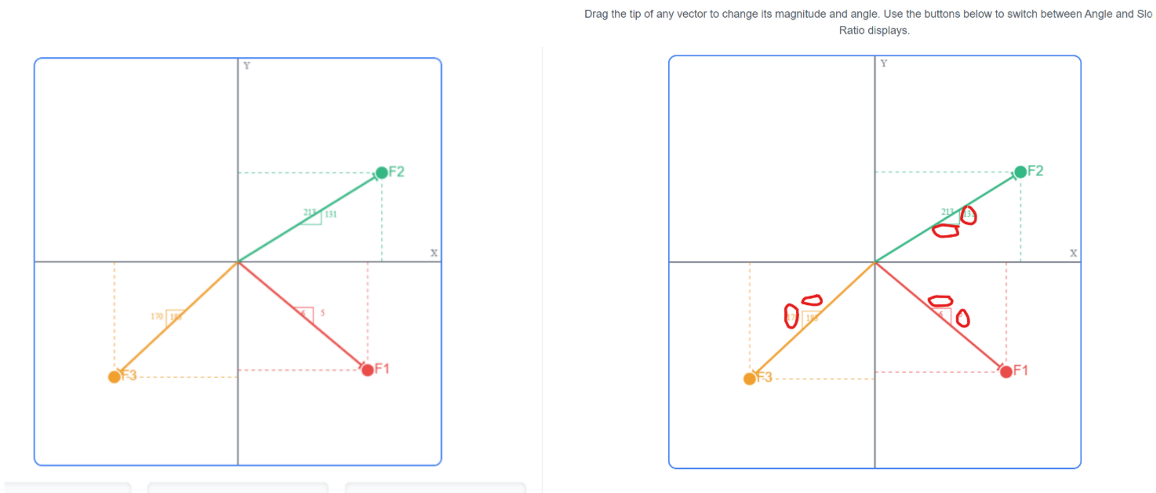
In addition to the Hunter model, we utilized a contemporary modified behaviorist instructional strategy referred to as the "I do-We do-You do" model. In this model, instructors perform the desired behavior for the students, the students work in groups, and then students work individually. During each of these phases, the instructor checks for common misunderstandings and errors. The Hunter model and the "I do-We do-You do" frameworks are often valued for their efficiency and demonstration of fuller, more in-depth skill development which is essential for a foundational engineering course such as Statics [14].

In generating behavioral objectives for each assignment, we utilized the Audience, Behavior, Conditions, and Degree (ABCD) objective approach [14]. In this framework, the objectives are developed regarding the audience, which is typically the students, the behavior is the observable skill or concept the students are learning, the conditions refer to the context for the behavior, and the degree is the level of accuracy required to complete the assessment successfully. Since the behaviorist approach emphasizes observable and measurable outcomes, assessment was also a consideration in the development of the virtual labs and accompanying activities. Our approach is a formative assessment based on whether students demonstrate mastery of the content presented in the "You do" portion of the virtual lab. Here students work independently on the topic covered in discussion and therefore this part of the virtual lab activity is graded for accuracy. For our assignments, we consider mastery of the topic to be a grade of 80% or better as this represents performance of a high level but not a perfect level as recommended in [15]. Since students have access to the virtual lab after the lab session, students who do not demonstrate mastery can repeat the activity with different variables and repeat the cycle until mastery is achieved. This is an additional benefit over the traditional hands-on labs.

To begin the actual development of the virtual labs, we started by selecting past problems that were previously used in the discussion sessions and input those into Gemini as a starting point for what we envisioned the interactive model would look like. From this starting point, we were able to make refinements and revisions to the model to produce the final desired outcome. We primarily used an iterative process of trial and error with Google Gemini for the code development, which led to insightful lessons learned. Each lab presented unique challenges and learning opportunities that informed subsequent development. One of the most critical skills we discovered for successful virtual lab development is learning how to effectively prompt a GenAI chatbot while also understanding the technical limitations of the resulting simulations. Establishing a consistent and structured prompting strategy proved essential to maintaining uniformity across all labs.

Each lab development process began with a standardized base prompt to ensure consistency in functionality, layout, and output format. The foundational prompt we used was: *"Generate an interactive lab simulation for undergraduate statics students. The main concepts of this lab are [insert main topics]. Using CSS, JavaScript, and HTML, create a 2D [or 3D] digital interface. The final output should be in one downloadable HTML file."* Using a consistent prompt assured that the generated code was uniform across labs, easily downloadable, and visually consistent.

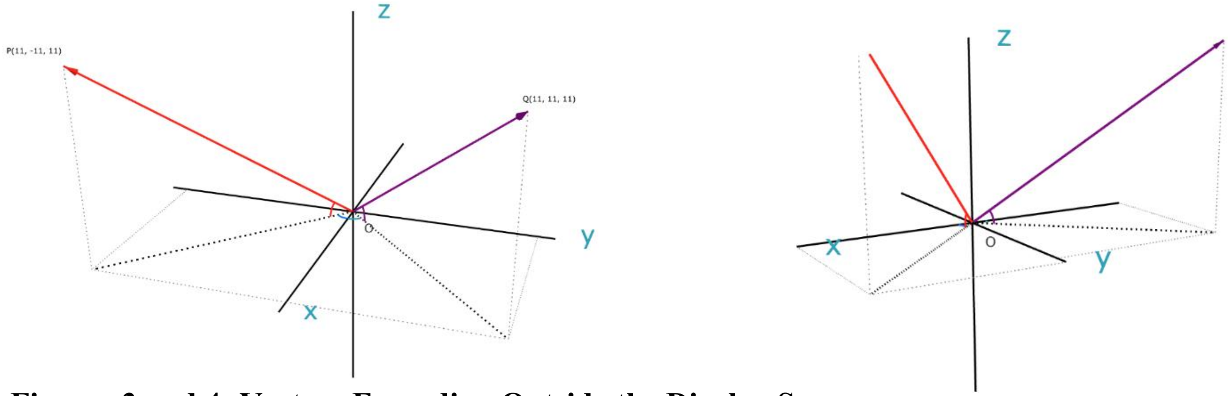
After the initial prompt, the generated code often contained functional or display-related errors that required further refinement. Addressing these issues involved iterative prompting to correct layout problems or logical errors in the code. As a highlighted example, we were challenged with a particular vector lab in which the slope triangle was displayed incorrectly and appeared reversed on the screen (Figure 1). To resolve this issue, a screenshot of the current display was captured and marked to indicate the desired orientation (Figure 2). Providing both the existing and intended display images alongside a clarifying prompt was the most effective method for correcting display issues. This approach allowed the AI chatbot to visually compare the current and desired outcomes and modify the code accordingly.



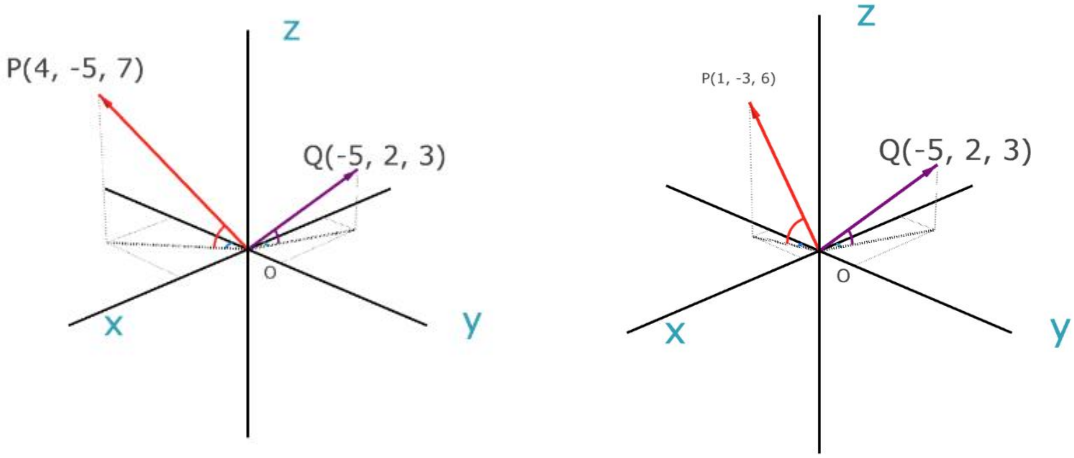
Figures 1 and 2: Resolving Slope Triangle Display

Additional challenges arose when attempting to create interactive 3D visualizations. Through experimentation, it was determined that Python-based environments using Plot.ly were better suited for interactive 3D displays. While JavaScript could generate 3D visuals, these displays lacked interactivity and were difficult to modify. Despite resolving many issues, several limitations remained within the virtual labs. For example, in one vector lab the vector's magnitude was restricted to a maximum x-value of eleven before it extended beyond the display window (Figure 3 and 4). In 3D simulations, text labels are rendered in perspective, causing font sizes to change dynamically as vectors are adjusted (Figure 5 and 6). Understanding these limitations is important, as it allows instructors to guide students within functional parameter ranges and avoid confusion during lab use.

Although we experimented with various concepts to gain a base understanding of how to work with GenAI chatbots in code development, we decided to limit our initial set of virtual labs and activities to vector addition of forces, structural analysis of simple trusses, and moments of inertia for composite areas. These topics were selected in part from Ramming and Phillips's [3] survey responses that asked students at Oklahoma State University retaking the Statics course in the Spring of 2013 what played the biggest factor in the outcome of their grade and based on grade performance on these topics over the past three years.



Figures 3 and 4: Vectors Exceeding Outside the Display Space



Figures 5 and 6: Display Issues with Perspective

In addition to these three virtual labs, structured worksheets were developed to accompany each simulation. For the worksheet development, we used the same conversation with Gemini that we used to develop the code and prompted Gemini to create a worksheet that accompanied the virtual lab since Gemini was already familiar with the previously input discussion problem. Additionally, we instructed Gemini to follow the "I Do-We Do-You Do" instructional framework and provided it with our Hunter model lesson plan, ABCD objectives, and the mastery evaluation process. By providing Gemini with this specific input, the pedagogical content produced was well aligned with our intentions. In early stages of worksheet development, we found that if we did not provide clear curriculum theory frameworks, the draft worksheets produced by Gemini required more manual revisions.

Even with a clear framework, the output from Gemini was ultimately only used to efficiently generate a draft worksheet. Gemini often struggled to accurately account for the specific capabilities, constraints of each virtual lab, and was not capable of knowing information that we wanted to include based on our experience of where students have struggled previously on similar assignments. AI-generated worksheets occasionally included errors or improperly formatted symbols, prompting the need for manual corrections to ensure the notation accurately reflected the concepts presented in the simulation. Additionally, AI chatbots frequently produced errors when formatting symbols, subscripts, and superscripts. As a result, the AI-generated worksheets served only as a starting point and were manually revised to align with the intended learning objectives, lab functionality, and professional formatting standards. It was observed that even with providing corrections to the worksheet, it was developed more efficiently and faster than if the worksheet were to be created without the use of Gemini.

Ultimately, using Gemini was successful in providing virtual labs and generating a draft of the worksheets efficiently. We took something that would not have been possible based on our current skill sets and created a virtual lab and worksheet (with revisions and refinements) in about one hour. The three finalized virtual labs, accompanying worksheets, and Hunter lesson plans are provided in the appendix to demonstrate what is possible when guidelines provided in this paper are used to develop a virtual lab.

Conclusions

The use of AI Chatbots, and particularly Gemini, to vibe code a functional interactive virtual lab for an Engineering Mechanics: Statics course was successful. While issues were presented in the development of these labs, they were able to easily be resolved with the assistance of Gemini and did not present substantial obstacles prohibiting the use of Gemini to vibe code an alternative learning aide. The lessons learned helped to provide cohesion and enhancements in further development of virtual labs. Without the use of Gemini, we would not have been able to entertain the development of these virtual labs due to our inexperience with coding. In a time when GenAI is one of the most popular emerging technology trends across all industries, and in particular education, one of the main issues is a lack of training and awareness of its potential for faculty members to use as a resource. We have presented one potential use case and determined the development of these GenAI tools has proven to be a helpful resource in the development of virtual labs. GenAI reduced the time required to develop the educational aides and provided assistance in coding that would otherwise not have been possible. It is desired in future work to employ the virtual labs into discussion sessions and perform qualitative and quantitative evaluation on student performance, grades, and retention rates compared to the current discussion session format.

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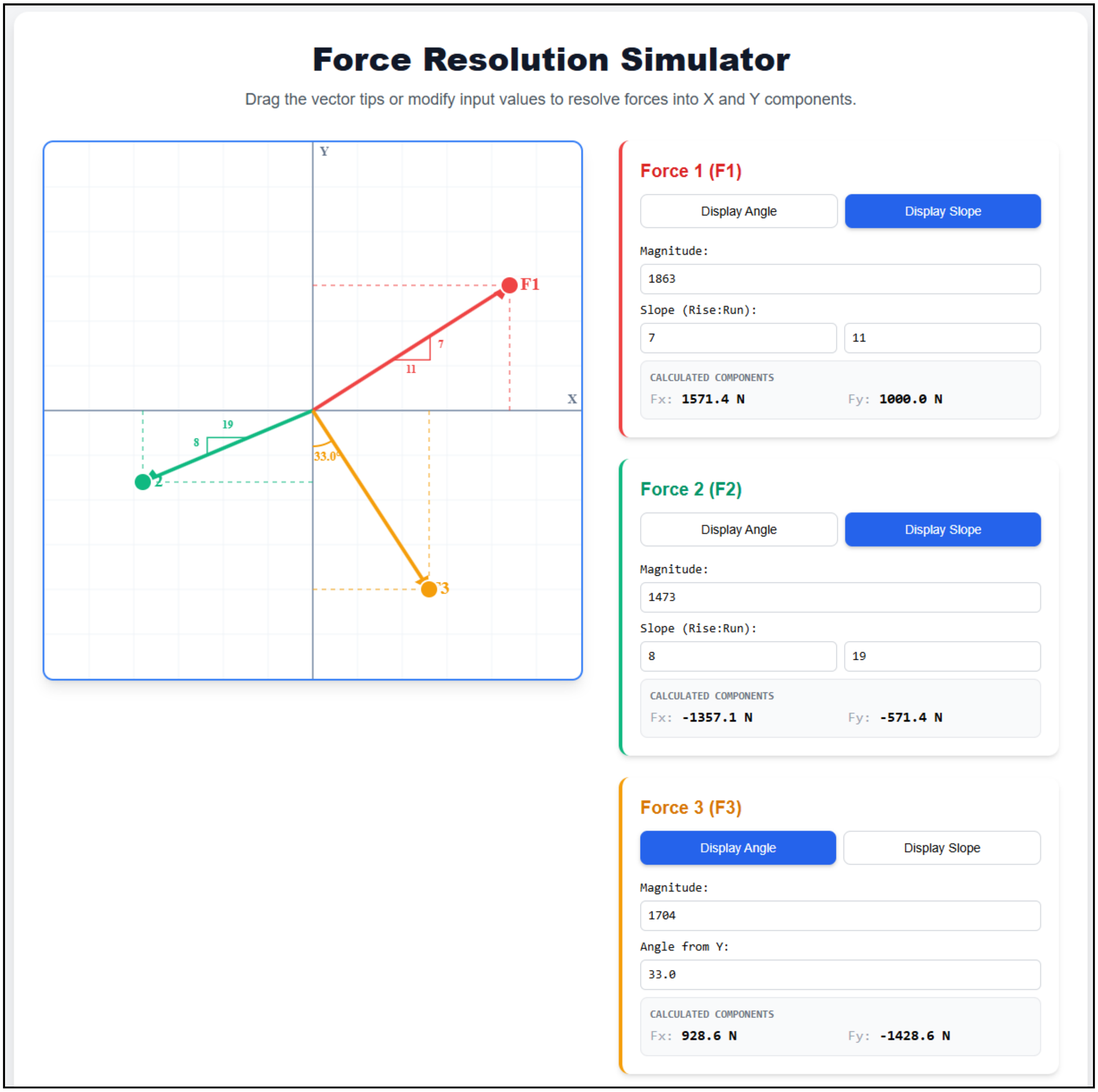
Appendix

The following is a screenshot of the opened .html file on an internet browser. An example configuration is provided for clarity is how the virtual lab may be used.



Hunter Lesson Plan – Force Resolution Virtual Lab Activity

Teacher Thinking…	**Students and Teacher Doing…**
Lesson Plan Element: Anticipatory Set	
How will I get students' attention and focus their learning?	Show students an example of a person kicking a soccer ball and ask, "If a player kicks a soccer ball with a force of 100 lbs, how much force is pushing the ball toward the goal and how much of it is working against gravity to lift the ball into the air?" Explain that forces in the real world are rarely pointed perfectly up or sideways. To design anything, engineers must break these slanted forces into horizontal and vertical components to better understand how objects move and how structures respond to loads. In this lesson, students will learn how to break forces down into components using angles and slope ratios.
Objective and Purpose	
State the ABCD learning objective(s) and the purpose for learning. How many do I need?	Students will accurately resolve 2D force vectors into horizontal and vertical components using slope ratios and angles with 80% accuracy. Read the objective and ask students, "'Why can't we just add the magnitudes of two slanted forces together?" Explain that forces are vector quantities, meaning that they have both magnitude and direction. If forces act at different angles, then they cannot be added together. With vector resolution engineers are able to add these forces together to accurately analyze structural members.
Input/Direct Instruction	
What kind of information must I provide so that students can meet the objective?	Remind students that the simulation follows the standard cartesian vector system. Explain that in the virtual lab, students can adjust the three force vectors using the control panel on the side. They can choose how each vector is displayed by selecting "Display Slope" or "Display Angle" to show the angle measurement. Students can also modify the magnitude of the force and the slope ratio directly in the control panel.
Modeling (I Do)	
What ways might I show the students the process or skill? What errors and misunderstandings do I	Using the .html file, demonstrate using the example in the worksheet how to use the .html file to change the force vectors angle, slope, and magnitude. Mention to students that this is one of the examples provided during a past

anticipate? How might I correct them?	lecture on Force Resolution. Highlight potential issues regarding load application (i.e. angle display or display limitations) Students will not need to record anything on the worksheet, this exercise is for them to watch and observe how to use the virtual lab .html file
Checking for Understanding	
How will I monitor their progress? Will this be informal or formal? Individual or whole group?	While performing the demonstration, stop periodically and ask the whole class about why forces need to be broken into components and how the process works. Allow students to volunteer to answer. Ask students to give a thumbs up, thumbs middle, or thumbs down to show how they feel about their understanding: thumbs up = I could teach it and thumbs down = no clue.
Guided Practice (We Do)	
What kinds of practice problems might I provide for the skills being taught? How can I organize them so they vary in complexity?	In small groups (2-3 students), students will work together to complete the guided practice portion of the worksheet which provides three force vectors with different angles and slope ratios. Students will work together to break down each of the force vectors into their respective components in the .html file. Students will work to fill out the questions provided in the worksheet, showing their work on completing the problem. The answer will be provided by the teaching assistant; however, the intermediate solutions will not be provided. Students who do not determine the correct solution will be encouraged to ask the teaching assistant for guidance on where they potentially made a mistake.
Independent Practice (You Do)	
What kinds of work should students practice independently toward mastery? Will this be done in class or for homework?	Students will work on the quiz portion of the worksheet which includes three different force vectors that they must resolve into horizontal and vertical components Students will complete the quiz but may use the .html file in order to check their final answer.
Evaluation and Closure	
What should I remind them about that we covered during the lesson? How will I do one	Review that force resolution is the process of breaking a force into its individual horizontal and vertical components. By resolving forces into these components, engineers can accurately analyze structural members and stability

<table>
<tr><td>last check for understanding?</td><td></td></tr>
<tr><td colspan="2">Materials:
Laptop or tablet with web browser capabilities (no internet access required) and a handout of the activities.
Time and Space:
50 minutes during the discussion session</td></tr>
<tr><td colspan="2">Reference for lesson plan layout:
C. McConnell, B. Conrad, and P. B. Uhrmacher, Lesson Planning with Purpose: Five Approaches to Curriculum Design. New York, NY, USA: Teachers College Press, 2020.</td></tr>
</table>

ENSC 2113 - Statics Interactive Lab: Force Vector Resolution

Student Name: ______________________________ **Date:** __________________

Objective: Correctly resolve the horizontal and vertical components of a force using slope ratios and angles with at least 80% accuracy.

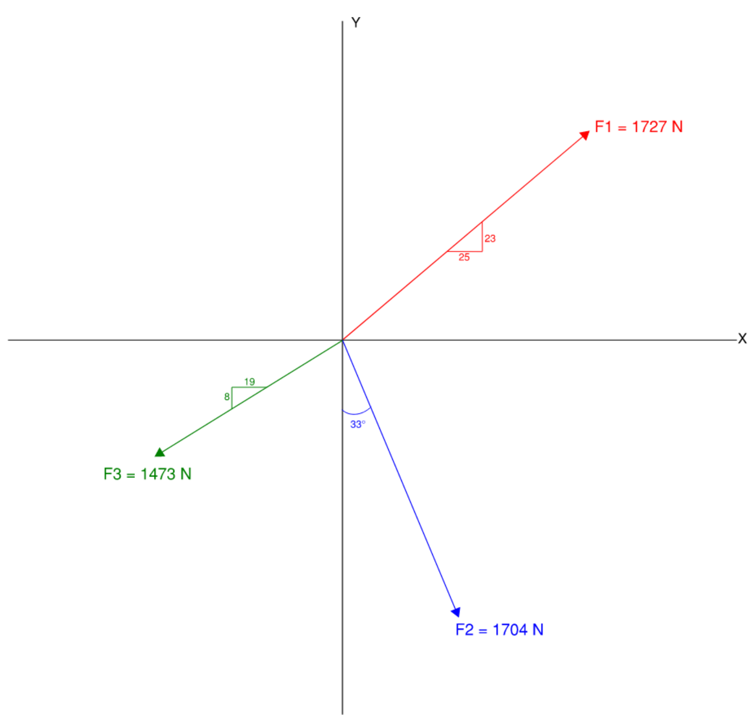
Part 1: Modeling – TA Demonstration

Problem: Replicate one of the lecture examples in the interactive lab to verify results and learn how to use the interactive lab software.

Instructions:

1. Open the ForceResolution_Lab.html file from Canvas.
2. Observe as the TA demonstrates how to use the simulation by toggling between the slope and angle display, adjusting the force magnitude and slope ratio, and clicking and dragging the vector to instantly change its direction and magnitude.
3. Key Concept: Notice how the components change based on the magnitude and direction of the force vector
4. Compare the software's "Force Results" values with your previous lecture notes.

Part 2: Guided Practice Problem: In groups of 2-3 students, calculate the horizontal and vertical forces for all three force vectors shown in the image shown to the right



Step 1: Draw a triangle for each vector and show the horizontal and vertical components

Step 2: Solve for the components using the slope ratios and the angle given

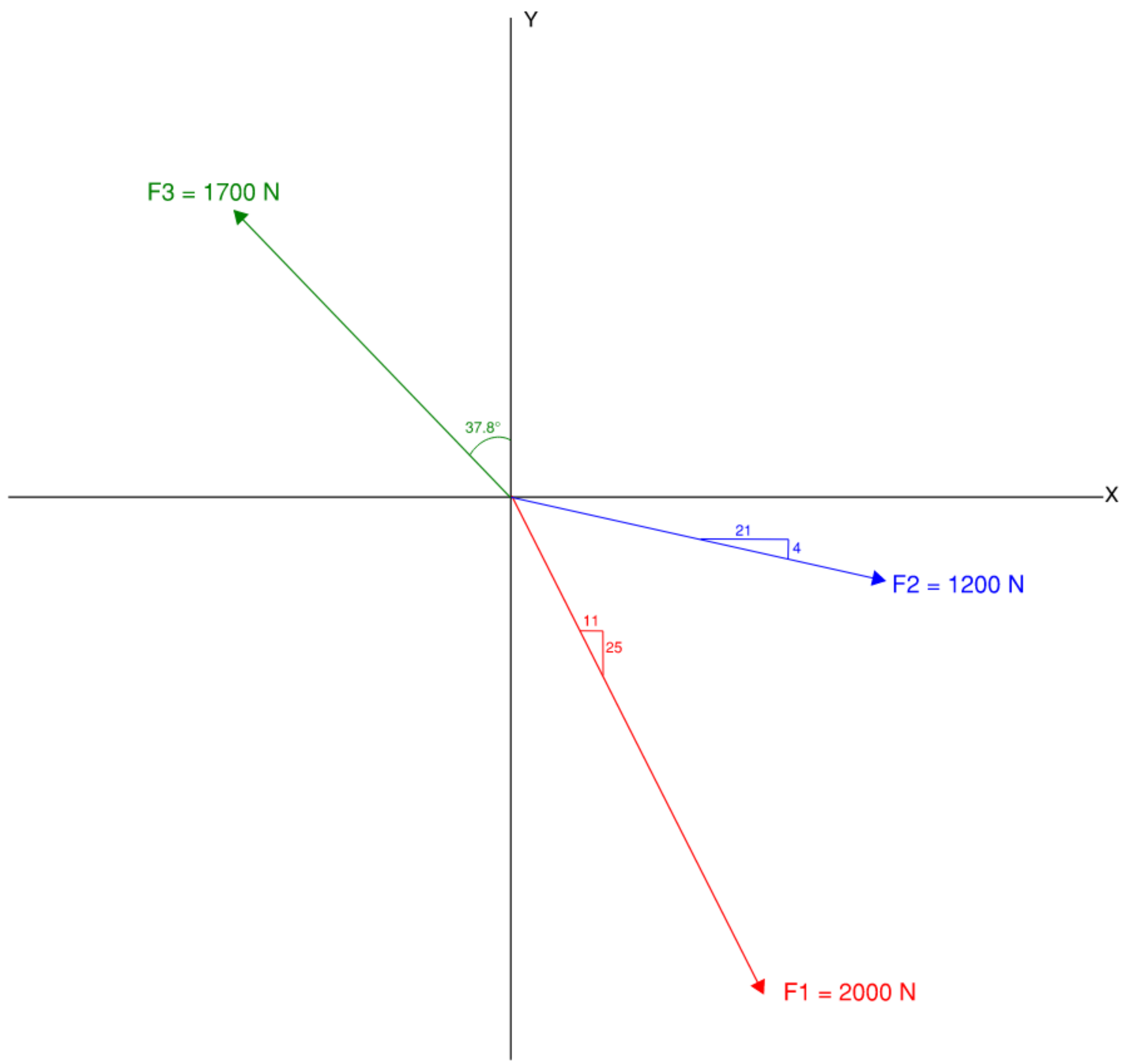
Step 3: Verification

Input these force vectors into the Interactive Lab. Does the software's force results match your horizontal and vertical forces calculated for each vector?

Part 3: Independent Practice (Graded Assessment)

Assessment Task: Determine the horizontal and vertical components of the three vectors shown below. You may use the interactive lab ONLY to check your final answer. You must show work and calculations for credit.

The Vectors:



Calculations:

Force 1:

F_x = ____

F_y = ____

Force 2:

F_x = ____

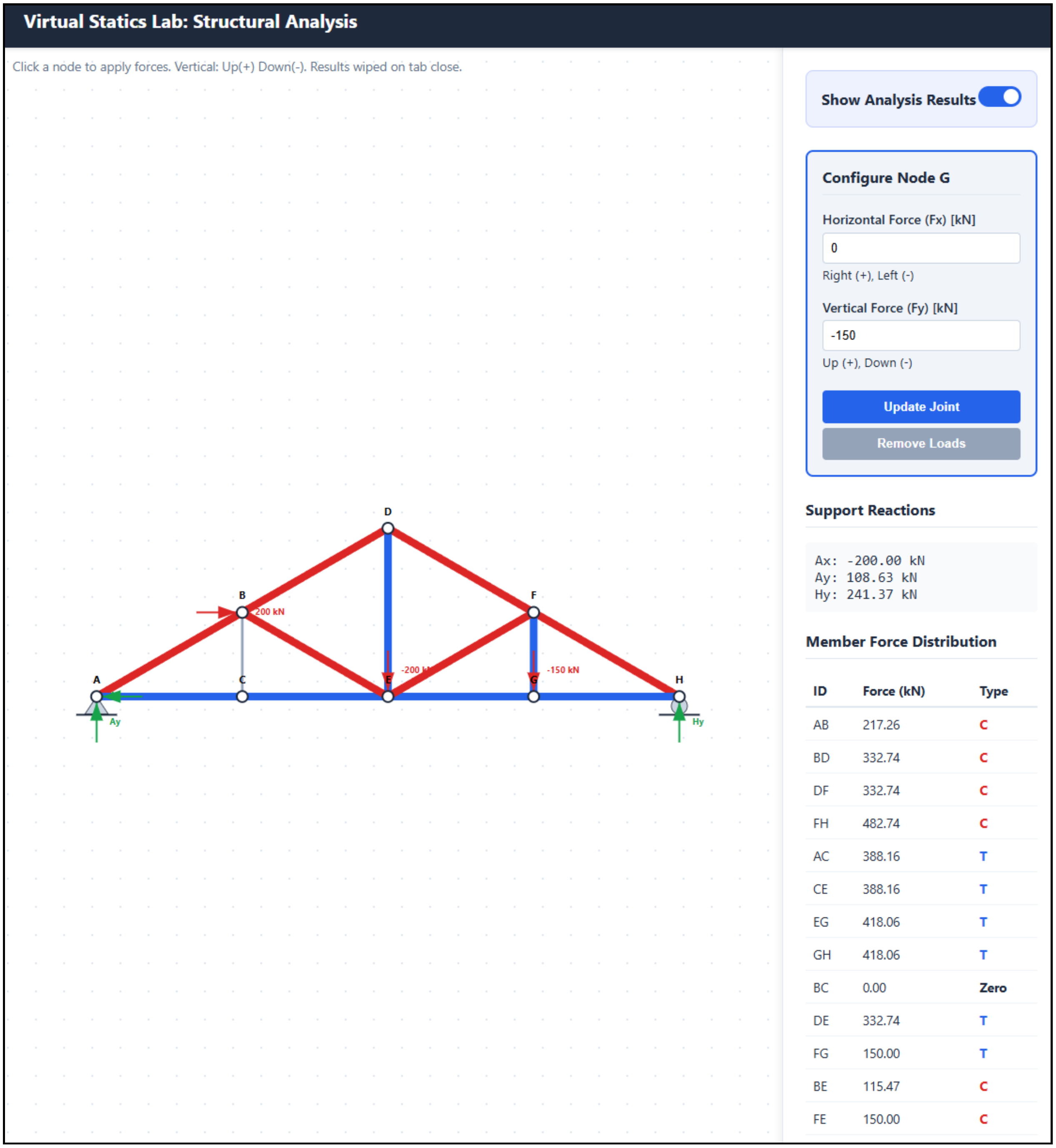
F_y = ____

Force 3:

F_x = ____

F_y = ____

The following is a screenshot of the opened .html file on an internet browser. An example configuration is provided for clarity is how the virtual lab may be used.



Hunter Lesson Plan – Truss Analysis Virtual Lab Activity

Teacher Thinking…	**Students and Teacher Doing…**
Lesson Plan Element: Anticipatory Set	
How will I get students' attention and focus on their learning?	Show students an example of a bridge made of trusses and ask, "Why is the bridge made of triangles instead of solid rectangular beams? If I place a heavy truck in the middle, how does the bridge know how to distribute the load?" Explain that the load path travels through the internal members as tension or compression forces. Today, we will visualize those invisible forces.
Objective and Purpose	
State the ABCD learning objective(s) and the purpose for learning. How many do I need?	Students will accurately calculate internal axial forces and support reactions for a static truss by applying the Method of Joints and the Method of Sections with 80% accuracy. Read the objective and ask students, "'Why must we solve for the internal forces of a truss?" Understanding these forces is the prerequisite for structural design; it allows engineers to calculate stress and select the correct material size and shape to prevent failure.
Input/Direct Instruction	
What kind of information must I provide so that students can meet the objective?	Remind students that for a truss to be in equilibrium, every individual joint must also be in equilibrium. We utilize equilibrium equations at every node to calculate the internal axial forces. Explain that in the virtual lab, the red arrows represent external loads applied to the joints. Highlight the sign convention used in our lab as well: vertical up is positive and horizontal right is positive.
Modeling (I Do)	
What ways might I show the students the process or skill? What errors and misunderstandings do I anticipate? How might I correct them?	Using the .html file, demonstrate using the example in the worksheet how to use the .html file to apply vertical and horizontal loads, how to clear the selection and how to see results. Mention to students that this is one of the examples provided during a past lecture on Stability Analysis. Highlight potential issues regarding load application (i.e. possible double application on joints) Students will not need to record anything on the worksheet, this exercise is for them to watch and observe how to use the virtual lab .html file

Checking for Understanding	
How will I monitor their progress? Will this be informal or formal? Individual or whole group?	While performing the demonstration, stop periodically and ask the whole class about which members would be in tension and compression for a truss based on the applied loads. Allow students to volunteer to answer. Ask students to give a thumbs up, thumbs middle, or thumbs down to show how they feel about their understanding: thumbs up = I could teach it and thumbs down = no clue.
Guided Practice (We Do)	
What kinds of practice problems might I provide for the skills being taught? How can I organize them so they vary in complexity?	In small groups (2-3 students), students will work together to complete the guided practice portion of the worksheet which provides a truss with external loads applied. Students will work together to insert the external loads onto the truss in the .html file. Students will work to fill out the questions provided in the worksheet, showing their work on completing the problem. The answer will be provided by the teaching assistant; however, the intermediate solutions will not be provided. Students who do not determine the correct solution will be encouraged to ask the teaching assistant for guidance on where they potentially made a mistake.
Independent Practice (You Do)	
What kinds of work should students practice independently toward mastery? Will this be done in class or for homework?	Students will work on the quiz portion of the worksheet which provides a truss with external loads applied. Students will complete the quiz but may use the .html file in order to check their final answer.
Evaluation and Closure	
What should I remind them about that we covered during the lesson? How will I do one last check for understanding?	Review how truss analysis is a critical foundation for designing structural members; it allows engineers to select appropriate materials based on force type, optimize members, and ensure the stability of structural members.
Materials: Laptop or tablet with web browser capabilities (no internet access required) and a handout of the activities. ***Time and Space:*** 50 minutes during the discussion session	
Reference for lesson plan layout:	

C. McConnell, B. Conrad, and P. B. Uhrmacher, *Lesson Planning with Purpose: Five Approaches to Curriculum Design*. New York, NY, USA: Teachers College Press, 2020.

ENSC 2113 - Statics Interactive Lab: Stability Analysis of Trusses

Student Name: ________________________________ **Date:** ___________________

Objective: Correctly determine the internal forces of truss members using method of sections with at least 80% accuracy.

Part 1: Modeling – TA Demonstration

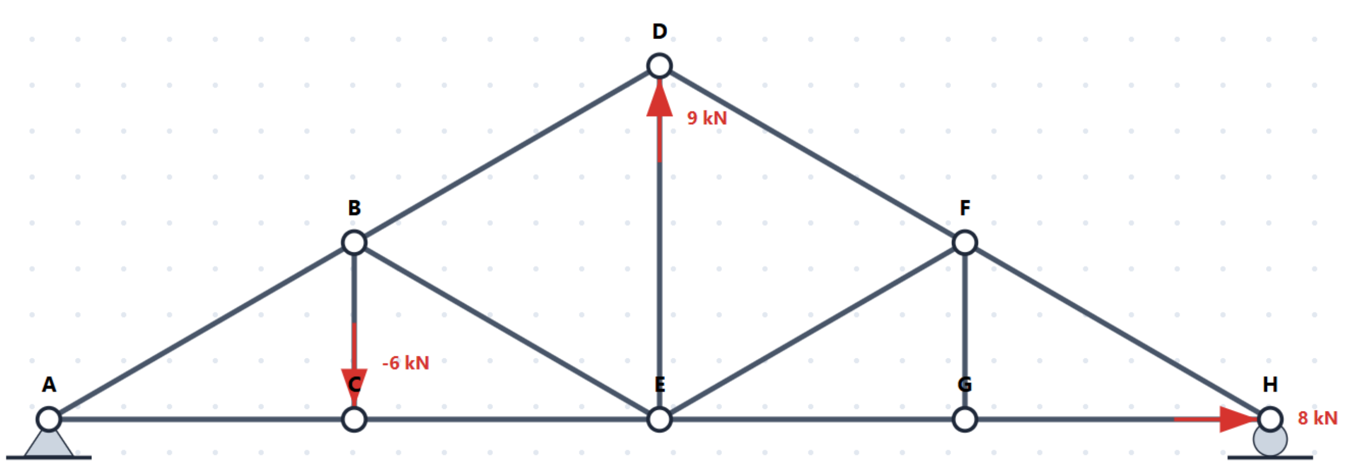
Problem: Replicate one of the lecture examples in the interactive lab to verify results and learn how to use the interactive lab software.

Instructions:

1. Open the Truss_Lab.html file from Canvas.
2. Observe as the TA applies horizontal and vertical loads on the joints, shows how to remove the forces, and toggles on and off results
3. Key Concept: Notice how the tension and compression members in the truss change based on where and what direction the load is applied in
4. Compare the software's "Truss Analysis Results" values with your previous lecture notes.

Part 2: Guided Practice

Problem: In groups of 2-3 students, calculate internal forces of members AB, AC, CE, BD and BC for the truss shown in the image below



Step 1: What are the zero force members?

$$Zero\ Force\ Members = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Step 2: What are the equilibrium equations for to determine the support reactions?

$\sum M_A = 0$

$\sum F_Y = 0$

$\sum F_x = 0$

Step 3: What are the support reactions and direction?

A_Y = ____ kN

A_x = ____ kN

H_Y = ____ kN

H_x = ____ kN

Step 4: Complete the method of joints at joint A and find the internal forces for members AB and AC

<u>FBD:</u>

<u>Calculations:</u>

Member AC = ________________________

Member AB = ________________________

Step 5: Complete the method of sections and find the internal forces for members CE, BD, and BC

<u>FBD:</u>

<u>Calculations:</u>

Member BD = ______________________

Member BC = ______________________

Member CE = ______________________

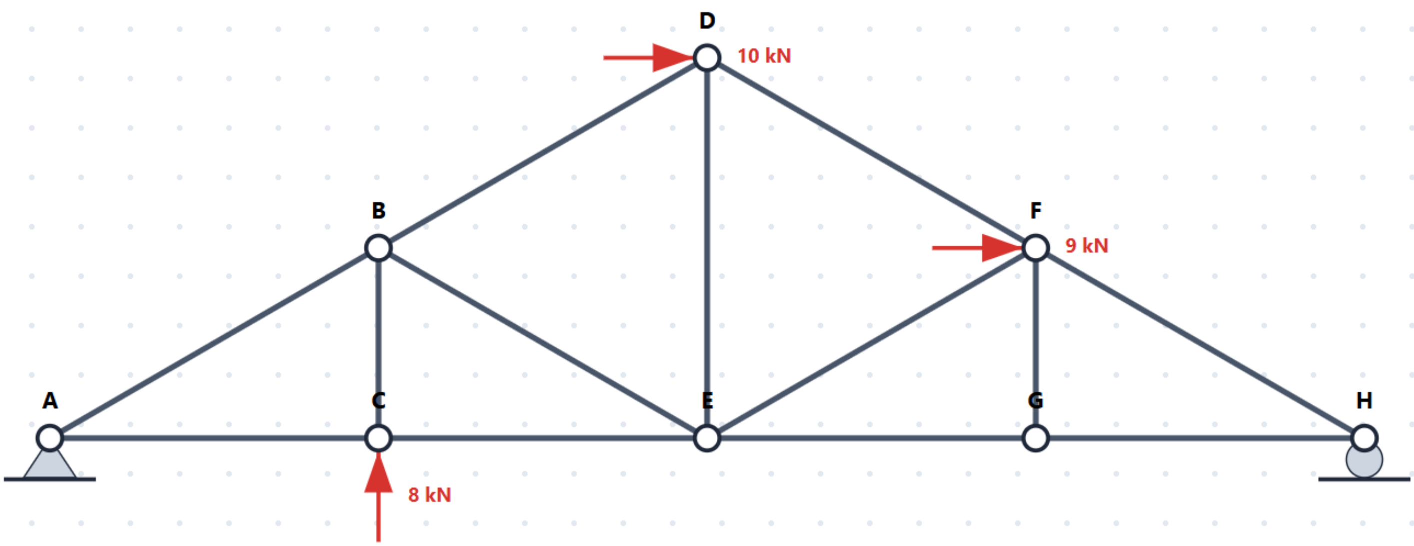
Step 6: Verification

Input these external loads into the Interactive Lab. Does the software's truss analysis results match your support reactions and internal member forces?

Part 3: Independent Practice (Graded Assessment)

Assessment Task: Determine the internal forces of members FD, FG, and GE using the method of sections for the truss shown below. You may use the interactive lab ONLY to check your final answer. You must show work and calculations for credit.

The Truss:



<u>FBD:</u>

Calculations:

A_y: ________________ kN

A_x: ________________ kN

H_y: ________________ kN

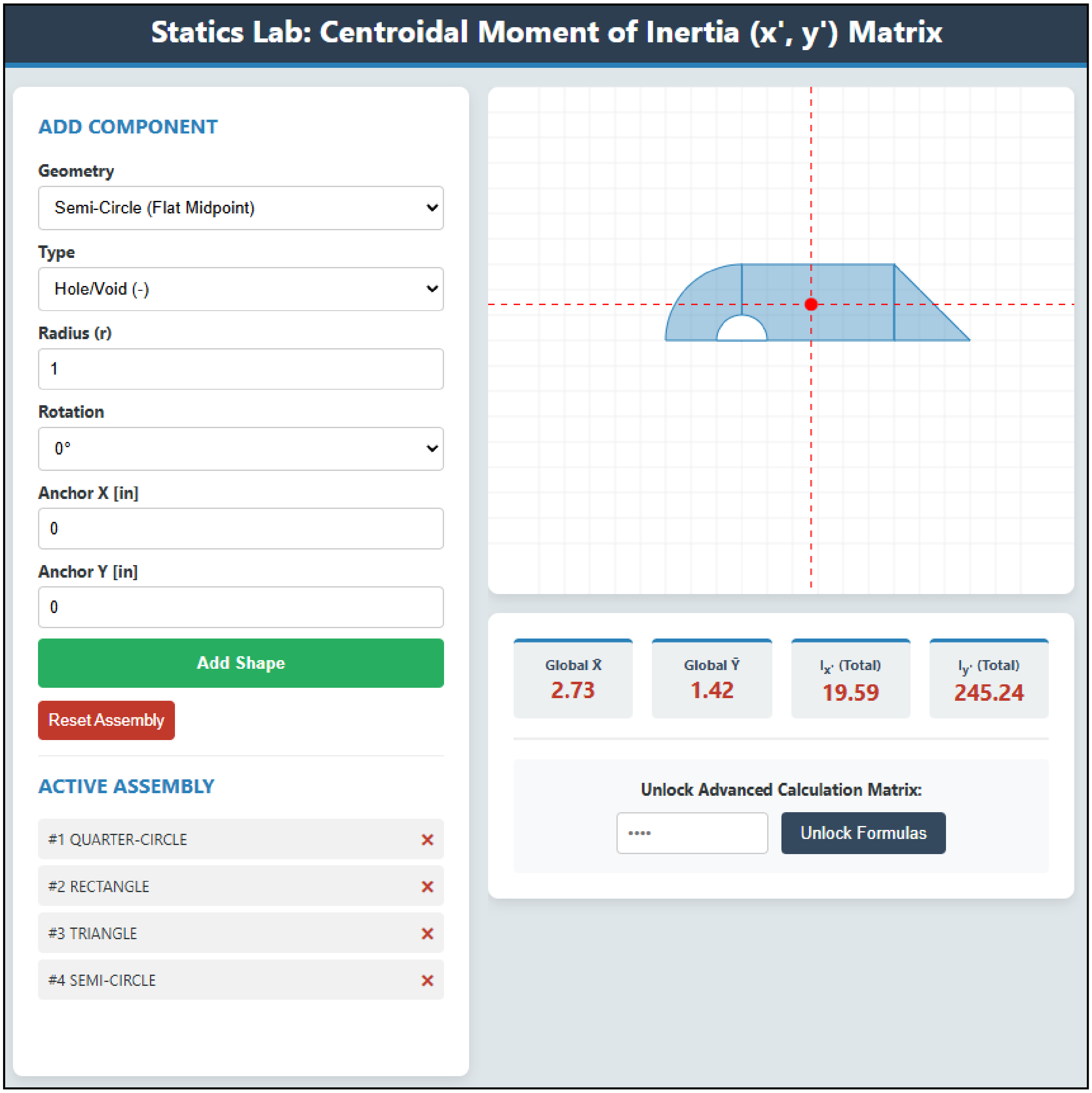
H_x: ________________ kN

Force of Member FD: ________________ kN

Force of Member FG: ________________ kN

Force of Member GE: ________________ kN

The following is a screenshot of the opened .html file on an internet browser. An example configuration is provided for clarity is how the virtual lab may be used.



Hunter Lesson Plan – Moment of Inertia Virtual Lab Activity

Teacher Thinking…	**Students and Teacher Doing…**
Lesson Plan Element: Anticipatory Set	
How will I get students' attention and focus their learning?	Hold up two 3D printed wide-flange beams, one with a depth large than the other Ask students, "If I placed the same large weight on top of these beams, which one do you think will deflect/sag more?" Explain that the distance from the center of the beam to the location with the most area (the upper and lower flanges) is a critical component of determining which one will deflect more. Let's investigate why this is.
Objective and Purpose	
State the ABCD learning objective(s) and the purpose for learning. How many do I need?	The students will be able to correctly determine the moment of inertia for an area of a composite shape using formulas and the tabular method with 80% accuracy. Read the objective and ask students, "Why is it important to determine the moment of inertia of a shape?" The moment of inertia is a geometric property of an area that is used to determine the strength of a structural member.
Input/Direct Instruction	
What kind of information must I provide so that students can meet the objective?	Remind students for composite bodies, we will utilize the parallel axis theorem equation for moment of inertia. $I_x = \bar{I}_{x'} + A{d_y}^2$ and $I_y = \bar{I}_{y'} + A{d_x}^2$. Highlight the importance of the square term and how that relates to the distance from the center of the beam to the location of the area that we discussed in the anticipatory set. Relate the tabular method we utilize for moment of inertia to the centroid problem, where each portion of the equation, (i.e. $I_x = \bar{I}_{x'} + A{d_y}^2$), is represented as the columns of the table.
Modeling (I Do)	
What ways might I show the students the process or skill? What errors and misunderstandings do I	Using the .html file, demonstrate using the example on the worksheet how to use the .html file to build the composite shape. Mention to students this is one of the examples provided during a past lecture on Moment of Inertia.

anticipate? How might I correct them?	Highlight potential issues regarding the shape type (i.e. the quadrants for the quarter circle). Students will not need to record anything on the worksheet, this exercise is for them to watch and observe how to use the virtual lab .html file.
Checking for Understanding	
How will I monitor their progress? Will this be informal or formal? Individual or whole group?	While performing the demonstration, stop periodically and ask the whole class which shape type they would select for the specific shape you are about to model. Allow students to volunteer to answer. Ask students to give a thumbs up, thumbs middle, or thumbs to show how they feel about their understanding: thumbs up = I could teach it and thumbs down = no clue.
Guided Practice (We Do)	
What kinds of practice problems might I provide for the skills being taught? How can I organize them so they vary in complexity?	In small groups (2-3 students), students will work together to complete the guided practice portion of the worksheet which provides a composite shape. Students will work together to insert the composite shape into the .html file. Students will work to fill out the table provided in the worksheet, showing their work on completing the problem. The answer will be provided by the teaching assistant; however, the intermediate solutions will not be provided. Students who do not determine the correct solution will be encouraged to ask the teaching assistant for guidance on where they potentially made a mistake.
Independent Practice (You Do)	
What kids of work should students practice independently toward mastery? Will this be done in class or for homework?	Students will work on the quiz portion of the worksheet which provides a composite shape. Students will complete the quiz but may use the .html file in order to check their final answer.
Evaluation and Closure	
What should I remind them about that we covered during the lesson? How will I do one	Review how the moment of inertia is an important geometric property that is used to determine the strength of a structural member.

last check for understanding?	Revisit the objective and purpose and discuss that students can now calculate the moment of inertia using the tabular method. Remind students that they may continue to practice with any composite shape they wish to create using the .html file in order to master this topic.

Materials:
Laptop or tablet with web browser capabilities (no internet access required) and a handout of the activities.

Time and Space:
50 minutes during the discussion session

Reference for lesson plan layout:
C. McConnell, B. Conrad, and P. B. Uhrmacher, *Lesson Planning with Purpose: Five Approaches to Curriculum Design*. New York, NY, USA: Teachers College Press, 2020.

NSC 2113 - Statics Interactive Lab: Moments of Intertia of Composite Bodies

Student Name: ______________________________ **Date:** __________________

Objective: Correctly determine the moment of inertia for a composite shape using the tabular method with at least 80% accuracy.

Part 1: Modeling – TA Demonstration

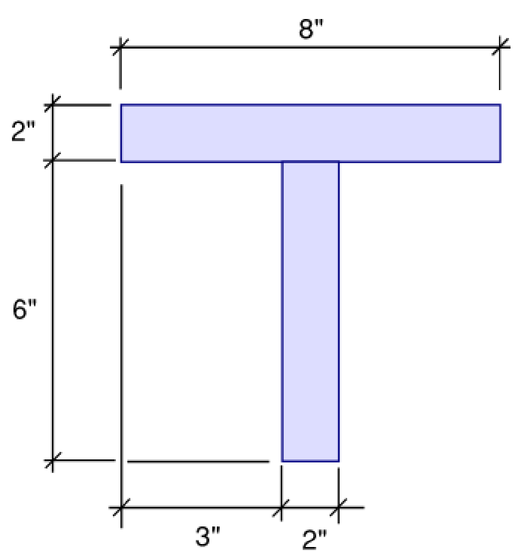
Problem: Replicate one of the lecture examples in the interactive lab to verify results and learn how to use the interactive lab software.

Instructions:

1. Open the MOI_Lab.html file from Canvas.
2. Observe as the TA inputs the dimensions and locations.
3. Key Concept: Notice how the global centroid (x', y') shifts as the "Hole" is subtracted.
4. Compare the software's "Total Area" and "Centroid" values with your previous lecture notes.

Part 2: Guided Practice

Problem: In groups of 2-3 students, calculate the Moment of Inertia about the centroidal x-axis ($I_{x'}$) for the T-Shaped beam shown below given $\bar{y} = 5.3$".



Step 1: What is the equation for $I_{x'}$?

$I_{x'} =$ ______________________________

Step 2: Fill out the Tabular Method Table

Shape	$\bar{I}_{x'}$ (in⁴)	A (in²)	dy (in)	Ady² (in⁴)
1				
2				
Σ				

Step 3: Verification

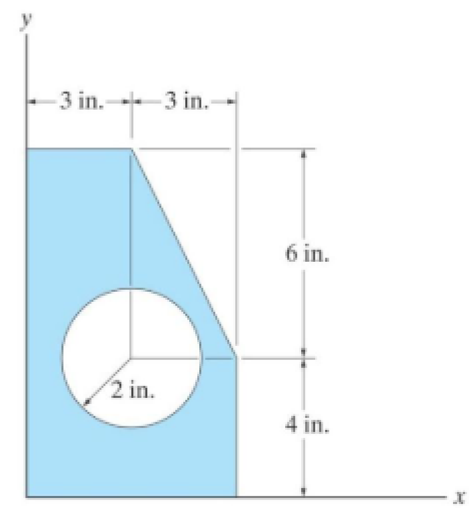
Input these shapes into the Interactive Lab. Does the software's $I_{x'}$ match your manual calculation? If not, identify if the error was in the $\bar{I}_{x'}$ formula or the Ad_y^2 term.

Part 3: Independent Practice (Graded Assessment)

Assessment Task: Determine the Moment of Inertia about the centroidal y-axis ($I_{y'}$) for the shape shown. You may use the Interactive Lab **ONLY** to check your final answer. You must show all tabular work for full credit.

The Shape:

$\bar{I}_{y'}$ =______________________



Calculations:

$\bar{I}_{y'}$ =______________________