Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #46684

Six Statics Activities in a Shoebox Kit

Dr. Christine F. Goble, Centre College

Christine Goble is an Associate Professor of Engineering at Centre College. She completed her bachelor's and master's degrees at the University of Kentucky and Ph.D. at Purdue University. She has 27 years of engineering education experience. Christine is actively engaged in developing an engineering degree program and educator training tools.

Dr. Martha E. Grady, University of Kentucky

Dr. Martha E. Grady (Meg) is the Associate Chair of the Department of Mechanical and Aerospace Engineering and Associate Professor at the University of Kentucky in Lexington, KY, USA. She obtained a Bachelor's degree in Mechanical Engineering from University of Central Florida, Masters and PhD degrees in Theoretical and Applied Mechanics from University of Illinois at Urbana-Champaign, and spent two years at the University of Pennsylvania as a Postdoctoral Fellow before beginning her faculty appointment. Beyond Dr. Grady's primary research in experimental mechanics, she enjoys developing hands-on activities for courses early in the engineering curriculum.

Six Statics Activities in a Shoebox Kit

Abstract

The purpose of this paper is to widely disseminate the resources required to implement a set of six hands-on statics activities. It is well established that active and hands-on learning can improve student outcomes. However, planning, resourcing, and implementation can be a barrier to their use. Our goal is to lower the implementation barrier for busy faculty that are hesitant to adopt active learning despite awareness of the research. We have created an easily accessible repository of the resources required to source, assemble, and implement Statics Shoebox Kits.

Five criteria were considered in the development of the kits and activities. 1) Very little prep time should be required from the instructor. 2) The materials should be readily available, portable, inexpensive, and reusable. 3) Activity worksheets and guidelines must be provided on a convenient platform that allows participants to share implementation experiences and make suggestions for improvement. 4) The kit design should be agile allowing for transition to an online learning format. 5) Activities should align with best practices in STEM pedagogy.

A detailed list of required resources for the Shoebox Kits is available in the Canvas Learning Management System (LMS). The kits include items such as K'nex pieces, PVC pipe, nails, bolts, rulers, and sandpaper; all of which fit in a shoebox sized container. A spreadsheet is provided for sourcing materials. Additionally, PowerPoint presentations and worksheets are provided for each activity. Along with the supplies list and teaching resources, the LMS offers an opportunity to ask questions or share implementation experiences. Currently, 38 participants are distributed at institutions across 19 states and territories. Institutions include large research universities, small liberal arts colleges, and minority serving institutions including one institution designated a Historically Black College and University (HBCU). We also recognize there is a great need for these activities to be agile and adaptable. The kits are designed to facilitate distribution to distance learning students and implementation on a virtual platform. Activities were designed to follow inclusive pedagogical practices such as collaborative learning, peer-to-peer instruction, real-world connection, immediate feedback, reflection, and low stakes assessment.

It is anticipated that this paper will increase dissemination of the Statics Shoebox Kit materials and result in an increased use of hands-on learning in engineering mechanics classrooms. Another benefit, already observed since the launch of the Canvas platform, is enhanced connections among statics instructors across the nation.

Introduction

An experience at the American Society for Engineering Education (ASEE) Annual Conference in 2017, where the authors presented hands-on activities for statics instructors, motivated the development of the statics shoebox kits. The presenting author was approached by several faculty to share these materials. From this experience, the authors realized there is a need for more hands-on statics activities and a platform to share them. The authors strive to offer practical content that enables faculty to easily integrate hands-on active learning into their teaching, helping them overcome common barriers.

These activities are intended to complement, rather than replace, traditional statics instruction, providing students with hands-on applications that reinforce key concepts. The design allows individual instructors the flexibility to draw connections between commonly used models in statics and their real-world variations, such as the assumption of frictionless pins in trusses. By incorporating these activities, instructors can contextualize theoretical assumptions and, when appropriate, facilitate discussions on model limitations to enhance student understanding.

Despite the known effectiveness of active learning, traditional lecturing is still the norm in college classrooms [1]. Even with the existing body of knowledge supporting active learning, many instructors remain hesitant to adopt the practice [2]. The main barriers to using active learning in higher education include faculty resistance or lack of training, unsuitable classroom layouts or large class sizes, time constraints for preparation and content coverage, and student resistance due to unfamiliarity or perceived inefficiency of active learning methods [2], [3], [4].

This work aims to reduce the challenges faced by engineering mechanics instructors in implementing hands-on active learning. To assist mechanics instructors in overcoming these barriers, Newton's Team has created a series of hands-on learning activities that use simple materials that fit into a shoebox sized container. Each activity can be implemented as provided with very little preparation time. Instructors also have the option to adapt the content to their teaching style. All content is shared in the Canvas Learning Management System (LMS), including a discussion board to address barriers such as a lack of student contact time. There is an initial time investment to procure and assemble the shoebox kits. The authors have simplified this initial step by providing a detailed list of required items with commerce links.

The shoe box kit, hands-on activities are designed to incorporate student-faculty interaction, collaborative learning, peer instruction, and real-world connections, all of which enhance student engagement and practical understanding [5]. These activities leverage instructional design principles such as just-in-time learning, feedback, and discovery [6]. Unlike traditional lectures, where information flows one way from expert to novice, active learning fosters two-way communication [7]. Rooted in Experiential Learning Theory (ELT), the activities provide opportunities for students to engage actively with the content [8].

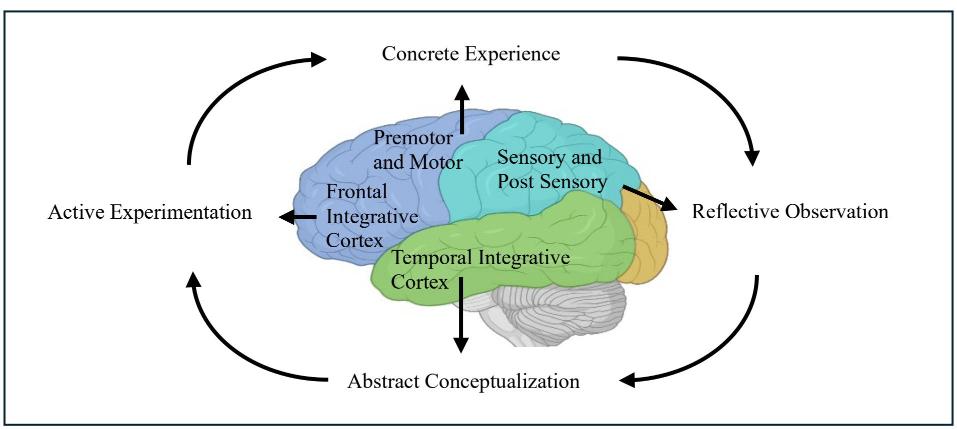


Figure 1. Experiential Learning Cycle and the Cerebral Cortex: Adapted from [10]

Active learning has been shown to improve student outcomes in science, technology, engineering and mathematics (STEM) [9]. Active learning has many definitions. In this work we will discuss active learning that involves the use of hands-on manipulatives. The terminology, hands-on active learning, will be used to describe hands-on learning activities that meet one or more aspects of the experiential learning cycle (Figure 1) [10]. The experiential learning cycle is the basis of Experiential Learning Theory [8].

Experiential Leaning Theory (ELT) models learning as a cycle of abstract conceptualization, active experimentation, concrete experience, and reflective observation [11]. In terms of action verbs, the cycle can be expressed as explaining, applying, experiencing and examining, respectively [12]. The learner may begin the cycle and any point. Each phase of the cycle uses a different region of the cerebral cortex and is essential in the learning process (Figure 1) [10]. When added to the traditional lecture and homework, the activities presented in this work ensure that learners engage in each phase of the cycle. Depending on when they are used in the learning cycle, the hands-on activities in the shoebox kit may support the concrete experience phase (experiencing) or the active experimentation phase (applying). The accompanying worksheets end with questions that lead to reflective observation. A PowerPoint presentation accompanies each activity to provide abstract conceptualization. As a result, all four aspects of the learning cycle are integrated.

For example, students entering statics typically have an intuitive understanding of centroids based on their concrete experiences, even if they lack formal terminology. The authors have observed that most students can reasonably estimate the centroid of an area. Activity 5 – Centroids, builds on this prior concrete experience. Students begin by estimating the centroid of an area using their experiential knowledge. The instructor presents the concept using the PowerPoint presentation, providing students with an abstract conceptualization of centroids. The concept presentation is followed by hands-on active experimentation to determine the centroid of the cardboard shape found in the shoebox kit. Finally, students reflect on their work, comparing the estimated and calculated centroid. The activity continues to move the student through the experiential learning cycle by asking them to derive the equation for centroid of a triangle then compare it to the equation provided in a table of the geometric properties of plane areas. The hands-on portion of Activity 1, Make Forces Work, can be used either as a concrete experience to introduce the concept of vector forces or later as active experimentation to engage students in application of their abstract conceptualization. The shoebox kit activities are easily adaptable. Instructors may choose to modify the activities and the presentations. The original, editable files are provided. Instructors are encouraged to share their modified content on the LMS.

Active learning not only enhances student performance metrics but also helps close achievement gaps for underrepresented students in STEM [13]. Research shows that hands-on learning has a particularly significant impact on female students [14]. Introducing hands-on active learning, like the materials proposed in this work, is generally beneficial to all students but especially to the students that tend to leave engineering. A key advantage of Experiential Learning Theory (ELT) is its ability to align the phases of the learning cycle with individual learning styles [15], meeting the needs of all students. Moreover, hands-on active learning establishes the relevance of course content—a critical factor in driving student interest and effort [16].

Development of Statics Shoebox Kits

In general, active learning works [9]. But new activities to reduce perceived barriers are needed as faculty and well-intentioned graduate teaching assistants are hesitant to adopt active learning despite awareness of the research [3, 17]. Motivated by personal experiences, the five guiding principles for creation of the kits were:

- Minimal instructor preparation time
- Portability, affordability, and reusability of materials
- Comprehensive resources and support on a convenient interactive online platform
- Flexibility for online and distance learning
- Alignment with best practices in STEM pedagogy

Minimal instructor preparation time

The six activities presented here can be implemented in part or whole of a regular 50-minute classroom period. The activities can be adapted to be performed as a demonstration to the class to work through or as a worksheet with kits shared by groups of students to perform together. The most time-consuming part is purchasing the items and assembling the kits. However, once this task is complete, implementing the activities in the classroom requires wheeling in the kits, printing the worksheets, and having the provided PowerPoint slides ready to go. Any statics instructor wishing to have access to these materials can request access to the Canvas course established by the authors of this work free of charge.

Portability, affordability, and reusability of materials

Components of the six activities fit inside a plastic bin about the size of a shoebox. The size of the kits is constrained by a 12-inch-long balance beam used in Activity 2 and Activity 6. The authors did not experiment with a shorter beam, however, if the readers are interested in using smaller boxes, shortening this beam by a few inches would not harm the activity. If the beam is too short, the students may have more trouble finding a good balance between the known weight and the unknown item and also find their calculations off from the measured weight, which is a less satisfying conclusion to the activity. The second item that limits the size of the container is the chosen centroid shape which has a length of 10 inches. Readers are welcome to modify this centroid shape for another, smaller, shape that can still achieve the practice of guessing the centroid and then using the integral method to make an accurate calculation. The authors sourced materials available in the machine shop on campus before purchasing materials to keep costs at a minimum and recommend the readers do the same. At the first implementation of the Shoebox Kits in 2020, the estimated costs to purchase all items brand new (ignoring any found items) was \$21.07 per kit for 30 kits. In 2024, we sourced items again to update the estimated cost and found the price to remain at around \$20 per kit for 30 kits. All materials in the kits can be reused from class to class, semester to semester, and year to year. After using for a significant period, the instructor may want to cut out new cardboard pieces for Activity 5 on centroids.

Comprehensive resources and support on a convenient interactive online platform

There are few online platforms that exist that share resources for implementing activities in the statics classroom. For example, the very useful Concept Warehouse online platform [18] connects statics instructors (and so many others!) to conceptual based questions. This resource is excellent and recommended by the authors of this work. Several choices for online platforms were considered including file sharing websites including Box, Dropbox, and Google Drive, however the authors wanted the ability to integrate surveys, announcements, and a visual interface that was more customized than those platforms allow. One advantage of using the Canvas LMS is that many instructors across the United States are already familiar with either Blackboard, Canvas, or another LMS, increasing the likelihood that faculty members are comfortable navigating its user interface. Microsoft Teams was also considered for this endeavor but was quickly dismissed after creating a few pages due to the challenges and frustrations it caused the authors. Key Canvas features utilized in this project included quizzes, which were assigned to instructors enrolled as 'students' in the course, discussion boards, and modules to organize materials for each activity.

Flexibility for online and distance learning

The first semester deploying the Shoebox Kits for statics was Spring 2021, when instruction was moved online. Kits were labeled and assigned to students who checked them out for the semester to perform the activities synchronously online via Zoom. Over 75% of the kits were returned at the end of the semester. Answers to questions were put into the private chat on Zoom to the instructor, who was able to respond to individuals or to the class. The instructor noticed more class participation when answers could be submitted privately and quickly, with personalized and private feedback, live in the Zoom chat as compared to an in-person class.

Alignment with best practices in STEM pedagogy

Lecturing for the entire class period remains the predominant mode of instruction in engineering courses[1]. Active learning is generally defined as any instructional method that meaningfully, intentionally engages students in the learning process [19]. Principles for good teaching practice often cite the use of active learning as a foundational principle [20]. Active learning interventions can vary widely in intensity and implementation as one study found [9], which included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. Hartikainen, *et al.* further define active learning in more granular categories, five of which are: student-centered, reflection and thinking, student action, collaboration, and activating activities [5]. The shoebox kits contain six student-centered active learning activities with manipulatives that each require student action and reflective thinking. Activities 2-6 require collaboration in pairs. Activity 1 is designed as an individual manipulative; however, materials can be shared among students to generate collaboration.

Statics Shoebox Kit contents and supporting documents

Materials and components of the kits for all six activities

Containers	Leftovers ? (Y/N)	Quantity	Unit Cost	Total Cost	Purpose			Vendor	Product Number
IRIS 6 Quart Plastic storage containers, 10 pack	N	3	32.99	98.97	Shoebox-sized container to hold activity items in the kit			Amazon	N/A
Box with handle	N	1	19.69	16.73	Hold leftover items in one place			McMaster	45865T25
Items in the kit	Leftovers ? (Y/N)	Quantity	Unit Cost	Total Cost	Activities			Vendor	Product Number
Flat head screws pack of 100	Y	1	$13.00	$13.00	#1 Make Forces Work			McMaster	90006A319
Nails, 1lb (about 150 nails)	Y	1	$4.62	$4.62	#1 Make Forces Work			McMaster	97850A230
Hex head screw bolts, pack of 100	Y	1	$16.28	$16.28	#1 Make Forces Work			McMaster	91236A591
Press to close bags, pack of 100	Y	1	$3.65	$3.65	#1 Make Forces Work			McMaster	1959T47
3D Printed Multi-tool	N	30	NA	NA	#1 Make Forces Work			N/A (3D Printed and optional)	
1215 Carbon steel, 1 ft, machined to size (steel ring)	N	2	$48.49	$96.98	#2 2D Equilibrium	#4 Trusses	#6 Friction	McMaster	4416T27
Rigid PVC pipe, length 5 ft	N	1	$11.40	$11.40	#2 2D Equilibrium			McMaster	48925K93
MDF Board. 36 boards cut from one sheet to be 12" by 2" wide	Y	1 sheet 12" x 72" x 1/2"	$48.98	$48.98	#2 2D Equilibrium	#6 Friction		McMaster	2726N73
Rulers, 12 pack	Y	3	$11.99	$35.97	#2 2D Equilibrium	#5 Centroids	#6 Friction	Amazon	N/A
Food scale	N	1	$12.22	$12.22	#2 2D Equilibrium			Amazon	N/A
K’nex thrill rides kit	Y	3 kits	$44.09	$132.27	#3 Support Reactions	#4 Trusses		Amazon	N/A
String	Y	1	$5.84	$5.57	#4 Trusses	#6 Friction		McMaster	2057T88-2057T882
Cardboard sheets, pack of 5	Y	1	$11.14	$11.14	#5 Centroids			McMaster	20585t22
Sandpaper, pack of 15, 120 grit	Y	1	$14.67	$14.67	#6 Friction			McMaster	4673A71
Double sided tape, 3 per order	N	10	$7.39	$73.90	#6 Friction			Office Depot	N/A
Total price for 30 kits			$	596.35					
Total price per kit			$	19.88					

Table 1: Materials and components needed for all six statics activities in a shoebox kit.

All the components and materials needed to create 30 statics shoebox kits are listed below in Table 1 and based on pricing in 2024, each kit costs $20 for a total cost of less than $600 for all kits. These numbers do include the shoebox-sized storage containers for the activities and the container to hold leftover components at the top of Table 1. Instructors can reduce the cost of implementing the proposed activities by making several modifications. For Activity 1, using smaller screws, bolts, and nails can lower material expenses. In Activity 2, instructors can opt for any available board, such as medium density fiberboard (MDF) or wood, rather than purchasing specific materials. To save on packaging, instructors can find more affordable kit boxes with the same dimensions. For Activity 2, instructors can also bring a food scale from home, eliminating the need to purchase additional equipment. In Activity 6, instructors can bring office tape from their department chair's office instead of buying new tape. For Activity 5, one option is to provide a printed outline of the centroid shape to exact scale and ask students to cut out their own cardboard piece using the printed shape as a guide. Lastly, for known weights, instructors can use canned food items as an affordable alternative to the steel ring used in Activity 2, 4 and 6. If a can of beans (approximately 1 lb) is chosen, there’s an opportunity to discuss tip verses slip in Activity 6 on friction.

Activity 1 – Make Forces Work for You

The objective of Activity 1 is to introduce students to terminology, units, and magnitudes of a force, a force couple, and a moment produced by a force at a distance. Students are provided a nail, screw, bolt, and a 3D printed multi-tool that can act like a screwdriver, hammer, and socket wrench (Figure 2). A hammer and nail pair represents an applied force. A screwdriver and screw pair represents a force couple. A socket wrench and bolt represent a moment created by a force at a distance. The gcode and stl files for 3D printing the multi-tool are free to download from the Canvas course. Two slides are provided in Figure 2 that cover the force couple portion of the activity. The instructor will help students recall how to write vectors, the vector convention used in the course, and how to determine the magnitude of a vector. Slides are intended to be posted for students to download to personal computers and tablets prior to the start of class.

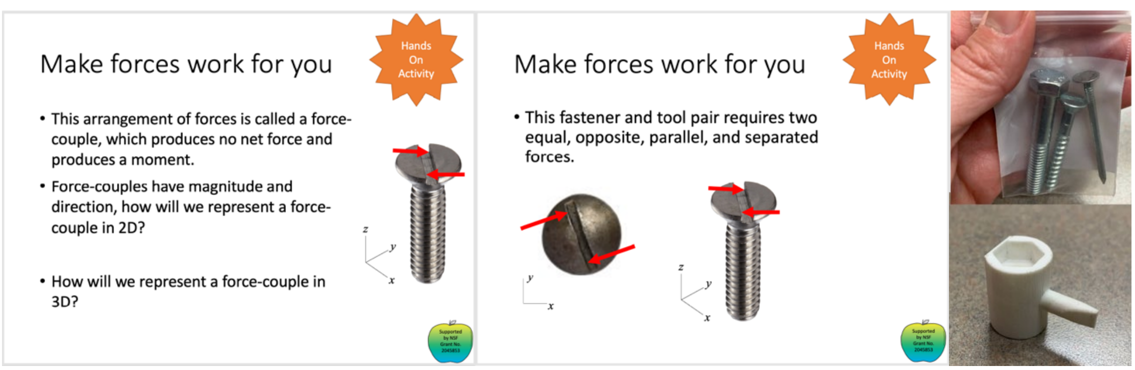


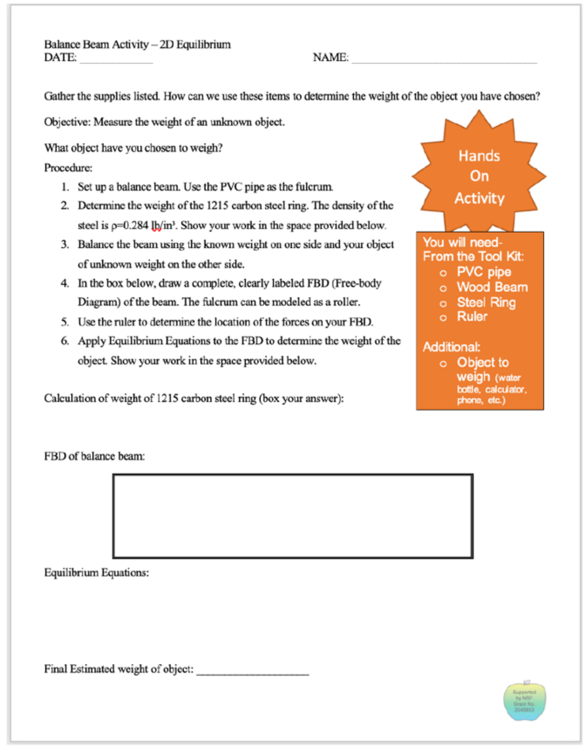
Figure 2. Representative slides from Activity 1 introducing a force couple through use of a tool and fastener. Students are provided with a screw and multitool to manipulate during the activity. Complete slide deck for Activity 1 also includes an applied force, represented by a hammer and nail and a moment produced by a force at a distance represented by a socket wrench and bolt.

Alternatively, slides for Activity 1 can be printed as handouts. During class time, the instructor has several options. The instructor can use a tablet to fill in portions on the slides (preferred method), use a document camera to write on printed handouts, or use a computer to display the slides and write on a board within the classroom.

Activity 2 – 2D Equilibrium

The objective of Activity 2 is to use a balance beam to determine the weight of an unknown object using an object of known weight. Students are provided with a short 1” section of PVC pipe, a wood beam, a steel ring, and a ruler. The instructor has a digital scale. Students choose an object of unknown weight. Students typically choose a cell phone, a calculator, or a water bottle. Students are given the density of the steel ring and must calculate its weight, which requires subtracting the volume of a cylinder using the inner dimension (the hole) from the volume of a cylinder using its outer dimension. Students place the PVC pipe as a fulcrum with the wood beam and try to balance one side with the steel ring and one side with the object of unknown weight.

Students are required to draw a free body diagram of the wood beam with the PVC pipe acting as a roller. Students are asked to apply equilibrium equations to estimate the weight of the object of unknown weight. During this process, students will need to measure the distance of the center of the steel ring to the fulcrum and the distance of the center of unknown weight to the fulcrum. The worksheet (Figure 3) includes a line for students to estimate the weight of the object with unknown weight. This activity is done in pairs. When a pair of students have completed their worksheet, they bring the worksheet and the object of unknown weight to the instructor who then weighs the object. Students get immediate feedback on whether their estimate was correct.



Balance Beam Activity – 2D Equilibrium
DATE: ____________ NAME: ______________________________

Gather the supplies listed. How can we use these items to determine the weight of the object you have chosen?

Objective: Measure the weight of an unknown object.

What object have you chosen to weigh?

Procedure:

1. Set up a balance beam. Use the PVC pipe as the fulcrum.
2. Determine the weight of the 1215 carbon steel ring. The density of the steel is ρ=0.284 lb/in³. Show your work in the space provided below.
3. Balance the beam using the known weight on one side and your object of unknown weight on the other side.
4. In the box below, draw a complete, clearly labeled FBD (Free-body Diagram) of the beam. The fulcrum can be modeled as a roller.
5. Use the ruler to determine the location of the forces on your FBD.
6. Apply Equilibrium Equations to the FBD to determine the weight of the object. Show your work in the space provided below.

Hands On Activity

You will need-
From the Tool Kit:
- PVC pipe
- Wood Beam
- Steel Ring
- Ruler

Additional:
- Object to weigh (water bottle, calculator, phone, etc.)

Calculation of weight of 1215 carbon steel ring (box your answer):

FBD of balance beam:

Equilibrium Equations:

Final Estimated weight of object: ________________

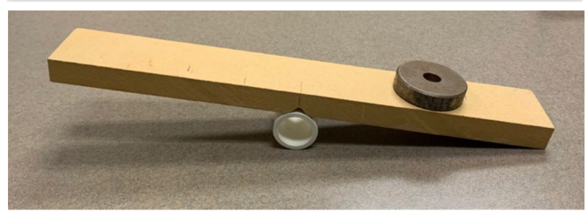


Figure 3. Worksheet for Activity 2 on 2D equilibrium. Representative slides from Activity 1 introducing a force couple through use of fasteners. Students must use a balance beam with a known weight to estimate the weight of an unknown object using equilibrium equations.

The Activity 2 worksheet can be printed for the class period for each student. Alternatively, the worksheet can be posted for students to download to personal computers or tablets prior to the start of class. Printed and completed worksheets can be collected in class, students can be directed to use a scanner app to scan and upload to an online learning module like Canvas, or students can use a tablet or personal computer to upload the previously downloaded worksheet to the online learning module. The instructor can use the Activity 2 slides to introduce the activity and help pace the students performing the activity. Alternatively, the instructor can use the slides to complete the activity as a class demonstration where the instructor weighs a single object of unknown weight. This alternative approach is better suited for very large class sizes, e.g., over 100 students, where even a group activity is cost prohibitive, or for classrooms without flat surfaces upon which to work the activity, *e.g.*, a seminar room with theatre-style seating.

Activity 3 – Support Reactions

The objective of Activity 3 is to build a 3D structure with K'nex that incorporates different support types. Students are provided with K'nex pieces to build a lollipop beam structure shown in Figure 4. Students draw appropriate diagrams and answer questions on the worksheet. Students are asked to identify a simple support, a pin, a fixed support, and a slide support, which are all represented in the structure. Students are also asked about what motion is allowed and what motion is restricted. Lastly, students are asked to draw a free body diagram of a selected component. The Activity 3 worksheet can be printed for the class period for each student. Alternatively, the worksheet can be posted for students to download to personal computers or tablets prior to the start of class. Printed and completed worksheets can be collected in class, students can be directed to use a scanner app to scan and upload to an online learning module like Canvas, or students can use a tablet or personal computer to upload the worksheet to the online learning module. The instructor can use the Activity 3 slides to introduce the activity and help pace the students performing the activity. Alternatively, the instructor can use the slides to complete the activity as a class demonstration where the instructor has a completed lollipop beam structure prepared to show the class via a document camera. This alternative approach is better suited for very large class sizes, *e.g.*, over 100 students, where even a group activity is cost prohibitive.

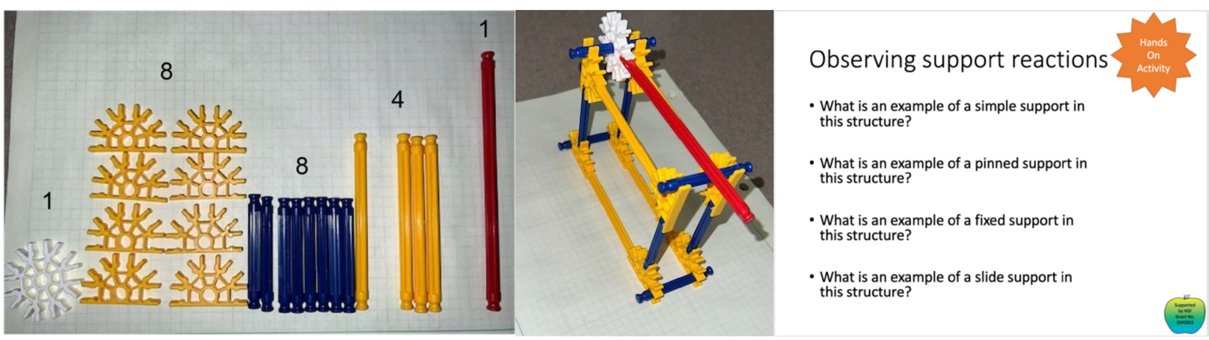


Figure 4. Image of the KNEX materials needed for Activity 3 on support reactions (left). Image of completed lollipop beam structure (middle). Example slide of the questions asked to students about the lollipop beam structure (right).

Activity 4 – Trusses

The objective of Activity 4 is to build and analyze a truss using K'nex. Students may also pair up with another group and try connecting the two sides so that it will be a free-standing structure. Part I is on identifying zero force members and Part II is on method of sections. Thus, this activity is best implemented after method of joints has been covered. In Part I, students are asked to draw a complete, clearly labeled Free Body Diagram of the 2D truss shown on the left that is loaded by 800 lb (Figure 5). Students then identify zero force members and are asked which of these can be safely removed from the structure and still maintain stability? In Part II Students are asked to determine the support reactions, draw a new free body diagram of the right section after a cut through members DE, BE, and BA. Finally, students are asked to determine the force in members DE, BE, and BA and state whether they are in tension or compression. The Activity 4

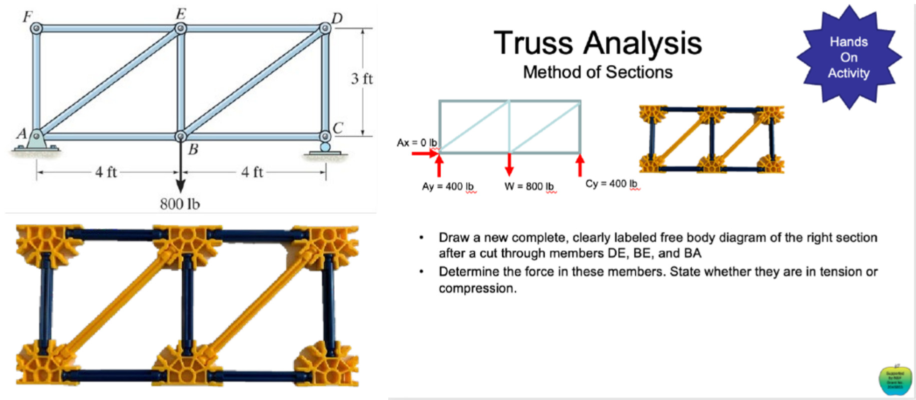


Figure 5. Schematic of truss problem and image of K'nex truss built by students (left). Example slide in Activity 4 on trusses Part II Method of Sections.

worksheet can be printed for the class period for each student. Alternatively, the worksheet can be posted for students to download to personal computers or tablets prior to the start of class. Printed and completed worksheets can be collected in class, students can be directed to use a scanner app to scan and upload to an online learning module like Canvas, or students can use a tablet or personal computer to upload the worksheet to the online learning module. The instructor can use the Activity 4 slides to introduce the activity and help pace the students performing the activity. Since this activity does not have as many moving parts, the authors suggest modifying the activity for use as a demonstration if class size or classroom prohibit students from manipulating the activity.

Activity 5 – Centroids

The objective of Activity 5 is to estimate the center of mass of the cardboard shape through an initial estimated guess and after calculating the centroid by method of integration. Students are provided with a specific cardboard shape (Figure 6). The cardboard shape can be shared between multiple students who mark their guess on the shape with a pencil and initial next to it. Students

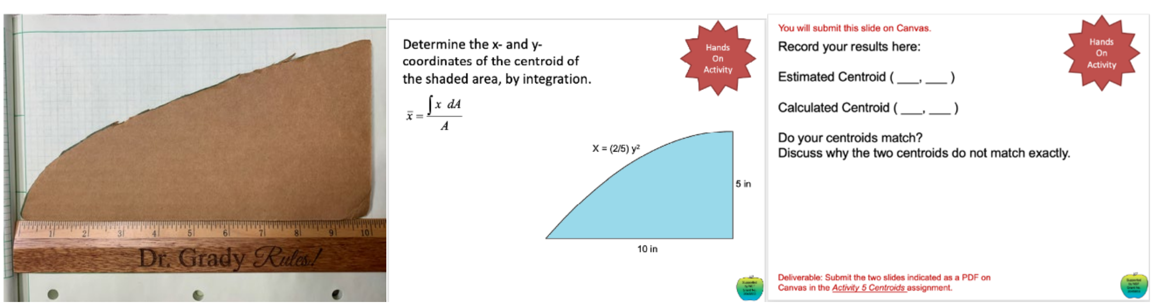


Figure 6. Image of cardboard shape (left) and example slides for Activity 5 centroids (right).

are also asked to reflect on their calculations and discuss possible reasons that their estimated centroid by balancing the board on their finger does not match the calculated centroid by the integral method. The activity is best completed through slides that have been provided to students ahead of time either in print or accessible as a download from an online learning module. The slides include methods of integration and additional slides introducing centroid calculations through the composite method. Slides are intended to be posted for students to download to personal computers and tablets prior to the start of class. Printing slides for Activity 5 is not recommended as the slides include animation and actions on mouse click that will not be appropriately accounted for in printed versions. During class time, the instructor fills in portions on the slides, which is best facilitated by using a tablet. If time allows, the students can be instructed to complete a third estimate of the centroid by the composite method, using a single triangle. Students may be surprised to find that their estimate by the composite method is actually quite close.

Activity 6 – Friction

The objective of Activity 6 is for students to solve problems of friction experimentally. Students are provided with a wood board, sandpaper, string, a steel ring weight, ruler, and double-sided tape. Students may need a stack of books or use the Shoebox Kit container itself. In Part I students will determine the coefficient of friction, μ_s, between the weight and the beam by lifting the beam to a position of impending motion (Figure 7). Students then tape sandpaper to the wood beam and repeat the process to determine the coefficient of friction, which should increase.

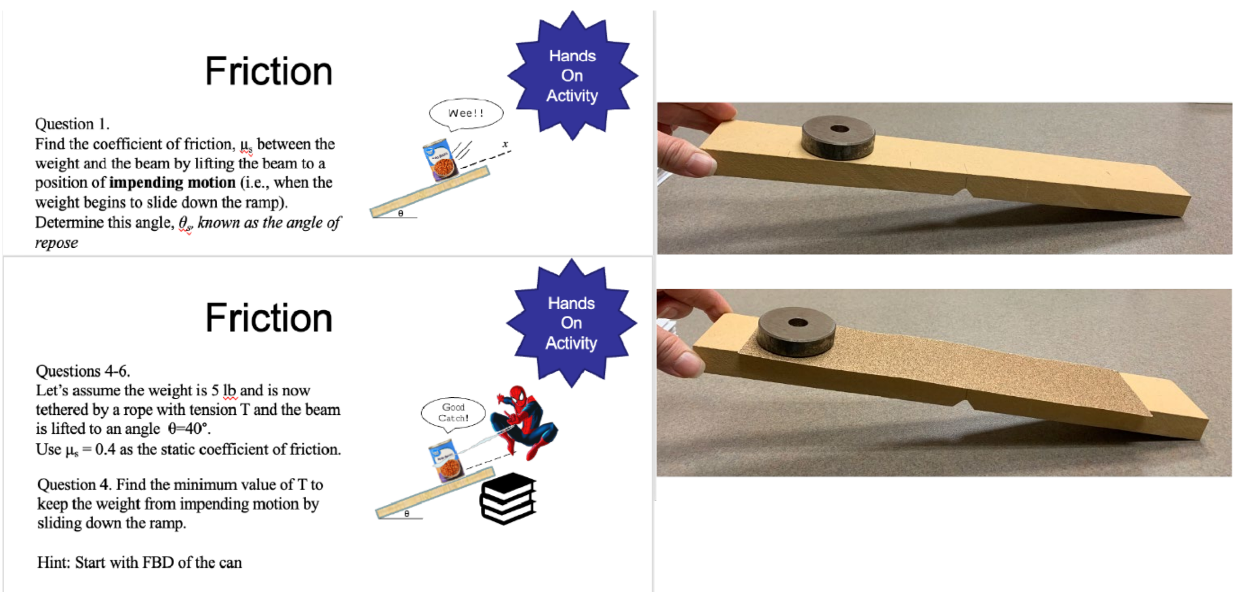


Figure 7. Example slide for Activity 6 friction (left), images of the activity to determine the coefficient of friction on the wood beam with and without sandpaper by lifting the beam until the weight begins to slide (middle), and a slide showing questions for Part II of the worksheet (right).

Students are then asked to think about the equation they used to calculate the coefficient of friction to answer the question, what if the weight is doubled? Some students try this experimentally by borrowing an additional ring from a neighbor's kit and find that the top ring slides off. This "failed" experiment is a useful learning opportunity where the instructor can hint at future problems the class will tackle with interacting bodies. In Part II students are now provided consistent values to work with to answer the remaining questions: Find the minimum value of T in the string to keep the weight from impending motion by sliding down the ramp. Find the maximum value of T to keep the weight from impending motion by sliding up the ramp. What will happen if the rope is cut? The last question requires students to think about when the rope is cut, it can no longer hold force, and thus, we have returned to a case where the angle of repose must be calculated and compared to the given angle in Part II [21]. The Activity 6 worksheet can be printed for the class period for each student. Alternatively, the worksheet can be posted for students to download to personal computers or tablets prior to the start of class. Printed and completed worksheets can be collected in class, students can be directed to use a scanner app to scan and upload to an online learning module like Canvas, or students can use a tablet or personal computer to upload the previously downloaded worksheet to the online learning module. The instructor can use the Activity 6 slides to introduce the activity and help pace the students performing the activity.

Documents accessible through Canvas LMS

All statics instructors are encouraged to email the authors to gain free access to the Canvas course Newton's Team. On the home page of the Canvas course, the instructor will find a tab that lists "Start Here," "Kit Basics," and "Apple Image." The "Start Here" tab communicates that the worksheets and PPT slides are available for free download and can be shared with colleagues. The logo, which is provided as a PNG download under "Apple Image," should be included on any materials downloaded from this Canvas account. The logo recognizing the grant number must be retained on these materials, though its size and placement can be adjusted as necessary. It is also requested that individuals sharing the material communicate this requirement to their colleagues. Included in the "Kit Basics" tab is a spreadsheet of materials to purchase, kit assembly guide with a word document checklist to make sure each kit has the necessary items to complete all activities, notes on implementation, and a list of ways to decrease kit costs. Activity 1 has an optional multi-tool that can be 3D printed from either the gcode or stl file provided on the Canvas site. In addition to modules that include worksheets and slides for download, there is a module to crowd source feedback called, "What are your Peers doing?" which includes several discussion boards that instructors can respond to including "Sharing other class demos and activities" and "Modification to the Six Kit Activities" as two examples. In each of the six modules covering each activity there is also a Canvas quiz for instructors to complete that has reflective questions on implementing that activity.

Implementation and usage

Classroom integration

The shoebox kit is designed so that most of the activities (Activities 2-6) are completed in groups of two to three students. The authors created 30 kits for an average class size of 60 students, so that students work in pairs for Activities 2-6. Activity 1 is designed as an each-gets-their-own such that there are three bags within each shoebox kit that each contain a nail, screw, and bolt. The optional 3D printed multitool can be included as a single item in the kit or can be printed in triplicate for each shoebox kit. From Table 1, instructors can identify activities that require very few materials or very many materials or use the table to identify materials that can be used for many activities and are thus worth the investment. Instructors may choose to use a document camera and complete part or all of the activities as a demonstration for the class when purchasing materials for many kits is cost prohibitive. On days where the kits are used, they are placed on a cart and wheeled to the classroom and divided up amongst students. The preferred classroom set up is with tables that provide space for setting up the activities as opposed to a movie theatre style room with only a flip-out desk top or no desk top at all.

Distance learning integration

The shoebox kits can be labeled and assigned to students for the semester. In a semester when mostly online (or so-called hybrid) courses were necessary, the authors assigned each student a kit, which required more kits than when the activities were completed as a group. Students picked up the shoebox kit on the first day of class and completed the activities during synchronous Zoom class periods that semester (Figure 8). There were several advantages to synchronous Zoom class periods over traditional in-person class that were noticed by the authors. For example, the instructor poses a question and has students complete the first part of an activity. The students are directed to use the private chat feature on Zoom to send the instructor their answer or to ask questions. This feature was heavily used by the students at a much higher rate than providing answers in class or asking questions in class in front of peers. The private chat function allowed students to make unsure guesses and ask for help in a low-stakes

Figure 8. Selective portions of a screenshot during synchronous zoom statics class Activity 4 on trusses (left). Photo taken by a student during the same synchronous zoom statics class of their truss and laptop set up (right). In the example images, students have removed the zero force members from the truss as a part of the activity.

environment compared to the traditional classroom. Students are often less inclined to offer unsure answers or ask for help in front of their peers [22]. Each student receiving their own kit also allowed students to explore the components of the kit in their down time. The portability of the activities, conveniently organized in a shoebox-sized container, facilitates their use in a virtual learning environment. At the end of the semester students were asked to bring their kit with them to the in-person final exam or drop it off to the instructor. There was a 75% return rate on the kits.

Instructor participation and feedback from students

Participating instructors

Newton's Team participants increased from the initial two authors of this work in 2021 to 37 participants distributed across 19 states and territories in 2024 (Figure 9). There are 7 institutions designated as a Minority Serving Institution and one institution from Historically Black Colleges

& Universities. Five participants are from institutions designated Private not-for-profit Colleges & Universities. Of the 32 participants at public institutions, 19 participants are at doctoral universities with either high research activity or very high research activity according to Carnegie Classification. The remaining participants at public institutions are at Associates, Baccalaureate, or Master's Colleges & Universities.

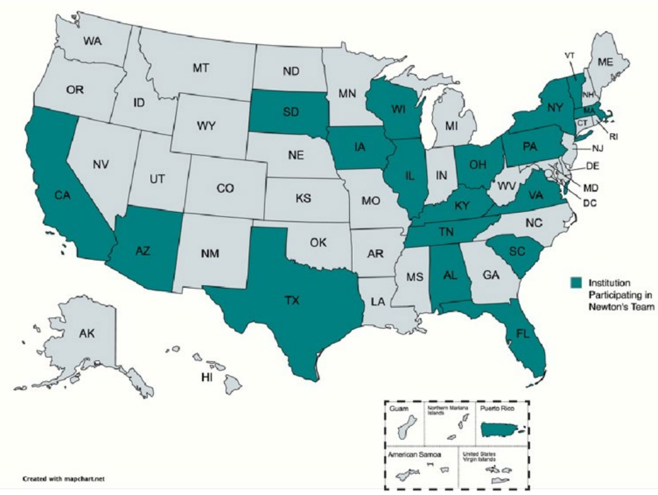


Figure 9. Map of United States and U. S. territories. There are 37 Newton's Team Participants distributed at institutions across 19 states and territories (green). Created with mapchart.net.

Student feedback

Student feedback from the online course revealed that the hands-on activities "lost their educational impact when we weren't in a classroom." However, it is challenging to distinguish between the students' views on the hands-on activities and the students' broader dissatisfaction with the sudden shift to online learning during the pandemic. Comments from that semester included statements like, "Difficult to pay attention when always outside of a traditional classroom setting" and "I desperately want to return to in-person classes," indicating a strong desire to return to a more familiar, in-person learning environment.

The feedback from students who took the class in-person highlights several aspects of the course that were particularly helpful, with a strong emphasis on hands-on activities and varied teaching methods. About 50% of the comments on the end of semester anonymous feedback over 3 years mentioned the in-class activities. One student noted, "The in-class activities were very helpful in furthering my learning." Students appreciated the opportunity to engage directly with the material, as one said, "The aspects of the course that were the most helpful were the hands-on activities that we would do at the beginning of new chapters. This allowed us to get a good grasp on the content before actually starting it." The instructor's approach was also praised, with comments such as, "The instructor provided many ways to learn, rather it be through lecturing or hands–on learning." Despite this, some students suggested improvements, such as incorporating "more activities throughout the class with group work" and making exams "worth a little less and have more in class activities." Overall, the most effective elements were the practical applications of learning, "The in–class activities were very helpful in furthering my learning. It gave me hands on application of the material we were learning in class," which reinforced course content and made it more accessible.

Challenges and lessons learned

Designing, assembling, and implementing the shoebox activity kits presented several initial challenges. Sourcing readily available, inexpensive materials was the first challenge. The fun part was playing with K'nex to determine the exact parts required to complete two of the activities then determining which K'nex kits would provide all the parts for the lowest cost.

Some materials were sourced from the department machine shop and a few required cutting or milling before use. A student designed the multitool and printed an adequate supply for the kits. There is an ongoing need to run inventory checks on the existing kits. The authors have found it best to provide an inventory list and have the students check the kits after the last activity of the semester.

The PowerPoint presentations and activity sheets were also a challenge. The authors worked to ensure they were based on sound pedagogy and tested in the classroom. The hope is continuous improvement of the content with input from additional users. Sharing the content also had its challenges. The Canvas LMS was chosen for its ease of use and ability to both host the content and allow for discussion and feedback. The content is updated regularly to ensure the kit cost and sourcing links are current.

Carving out class time to implement the activities is also a challenge. There is a discussion board on this topic in the LMS. The authors have used various strategies such as replacing some lecture time with video content. Overall, the gains in engagement and learning outweigh any loss in lecture time. Future improvements will focus on enhancing the feedback loop among statics instructors to continuously refine the design and usability of the kits.

Conclusion and future work

This work introduces shoebox kits to encourage implementation of hands-on active learning among statics instructors. By sharing their content and experiences, the authors aim to lower the barriers to implementing hands-on active learning. An additional benefit has been fostering a community among engineering mechanics instructors. The authors hope this initiative will reach more institutions and educators, cultivating a vibrant user community that shares experiences. The long-term goal is to facilitate resource sharing among instructors, potentially extending into other courses in engineering mechanics.

Acknowledgements

These hands-on activities were made possible by National Science Foundation CAREER Award grant number 2045853. The authors thank Dr. James D. Boyd for their contributions towards the activities.

References

[1] M. Stains *et al.*, "Anatomy of STEM teaching in North American universities," *Science (American Association for the Advancement of Science),* vol. 359, no. 6383, pp. 1468-1470, 2018, doi: 10.1126/science.aap8892.

[2] K. Børte, K. Nesje, and S. Lillejord, "Barriers to student active learning in higher education," *Teaching in higher education,* vol. 28, no. 3, pp. 597-615, 2023, doi: 10.1080/13562517.2020.1839746.

[3] M. E. Grady and G. Ryan Christopher Reuer, "What's Stopping Them? Perspectives of Teaching Assistants on Incorporating Diverse Teaching Methods," Atlanta, 2014: American Society for Engineering Education-ASEE, p. 24.1372.1.

[4] S. McCorkle, "Exploring Faculty Barriers in a New Active Learning Classroom: A Divide and Conquer Approach to Support," *Journal of Learning Spaces; Vol 10, No 2 (2021),* 2021. [Online]. Available: https://libjournal.uncg.edu/jls/article/view/2106.

[5] S. Hartikainen, H. Rintala, L. Pylväs, and P. Nokelainen, "The Concept of Active Learning and the Measurement of Learning Outcomes: A Review of Research in Engineering Higher Education," *Education sciences,* vol. 9, no. 4, p. 276, 2019, doi: 10.3390/educsci9040276.

[6] C. Finseth, *Teach Like a Gamer: Adapting the Instructional Design of Digital Role-Playing Games*. Jefferson, North Carolina: McFarland, 2018.

[7] C. Crockett, C. Finelli, and H. C. Powell, "Instructional factors influencing conceptual understanding of signals and systems," *European Journal of Engineering Education,* vol. 47, no. 6, pp. 1083-1102, 2022/11/02 2022, doi: 10.1080/03043797.2022.2116562.

[8] A. Y. Kolb and D. A. Kolb, "Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education," *Academy of Management Learning & Education,* Article vol. 4, no. 2, pp. 193-212, 2005, doi: 10.5465/AMLE.2005.17268566.

[9] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proceedings of the National Academy of Sciences - PNAS,* vol. 111, no. 23, pp. 8410-8415, 2014, doi: 10.1073/pnas.1319030111.

[10] J. E. Zull, *The art of changing the brain : enriching teaching by exploring the biology of learning*, 1st ed. Sterling, Va.: Stylus Pub., 2002. [Online]. Available: http://site.ebrary.com/id/11170610.

[11] D. A. Kolb, *Experiential learning : experience as the source of learning and development*. Englewood Cliffs, N.J: Prentice-Hall, 1984.

[12] M. D. Svinicki and N. M. Dixon, "The Kolb Model Modified for Classroom Activities," *College Teaching,* vol. 35, no. 4, pp. 141-146, 1987. [Online]. Available: http://www.jstor.org/stable/27558239.

[13] E. J. Theobald *et al.*, "Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math," (in eng), *Proc Natl Acad Sci U S A,* vol. 117, no. 12, pp. 6476-6483, Mar 24 2020, doi: 10.1073/pnas.1916903117.

[14] L. E. Carlson and J. F. Sullivan, "Hands-on engineering: Learning by doing in the integrated teaching and learning program," *The International journal of engineering education,* vol. 15, no. 1, p. 20, 1999.

[15] J. Meyer, "Experiential learning theory and individual learning styles," *South African Journal of Physiotherapy,* vol. 41, no. 1, p. 5, 1985/03/01 1985, doi: 10.10520/AJA03796175_1324.

[16] R. M. Felder, D. R. Woods, J. E. Stice, and A. Rugarcia, "The future of engineering education: Part 2. Teaching methods that work," *Chemical engineering education,* vol. 34, no. 1, pp. 26-39, 2000.

[17] M. Borrego, J. E. Froyd, and T. S. Hall, "Diffusion of Engineering Education Innovations: A Survey of Awareness and Adoption Rates in U.S. Engineering Departments," *Journal of Engineering Education,* Article vol. 99, no. 3, pp. 185-207, 2010, doi: 10.1002/j.2168-9830.2010.tb01056.x.

[18] M. D. Koretsky *et al.*, "The AIChE" Concept Warehouse": A Web-Based Tool to Promote Concept-Based Instruction," *Advances in Engineering Education,* vol. 4, no. 1, p. n1, 2014.

[19] M. Prince, "Does Active Learning Work? A Review of the Research," *Journal of engineering education (Washington, D.C.),* vol. 93, no. 3, pp. 223-231, 2004, doi: 10.1002/j.2168-9830.2004.tb00809.x.
[20] A. Chickering, "Seven principles for good practice in undergraduate education," *Johnson Foundation,* 1987.
[21] L. G. K. James L. Meriam, J. N. Bolton, *Engineering Mechanics: Statics*, 9th ed. John Wiley & Sons, 2018.
[22] E. M. Nadile *et al.*, "Call on me! Undergraduates' perceptions of voluntarily asking and answering questions in front of large-enrollment science classes," (in eng), *Plos One,* vol. 16, no. 1, p. e0243731, 2021, doi: 10.1371/journal.pone.0243731.