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# MULTIPLE INTERACTIVE HANDS-ON APPLICATIONS IN STATICS (BEST IN 5 MIN DEMONSTRATIONS SESSION)


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Dr. Mohammad Yamin is a Civil Engineering faculty who joined the Department of Mechanical and Civil Engineering at MSU Mankato Fall of 2017. He holds a Doctorate degree in Civil Engineering with an emphasis on Geotechnical Engineering applications from the University of Akron, Ohio. He obtained his Bachelor's and Master's degrees in Civil Engineering from Jordan University of Science & Technology, Jordan. Dr. Yamin is a licensed Professional Engineer (P.E.) in the States of Ohio and Minnesota. Prior to joining MSU Mankato, Dr. Yamin served as a faculty member at Bradley University in Peoria, IL, and as a visiting faculty member at the American University of Sharjah in the United Arab Emirates. In addition to his academic experience, Dr. Yamin worked as a design engineer in the Bridge Department at the California Department of Transportation, Sacramento, CA. He also worked as an Engineering Manager at Gulf Engineering House – a consulting firm in Saudi Arabia.

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Khosrow Ebrahimi joined Minnesota State University, Mankato in August 2018. In his current position, he teaches a wide variety of courses in the ME curriculum including Statics, Dynamics, Engineering Analysis, Fluid Mechanics, Heat Transfer, Applied Thermodynamics, Thermal Systems Design, Thermal-Fluid Experimentation, and HVAC Design. Before joining MNSU Mankato, he worked for one year as a full-time lecturer at Boise State University (BSU). He taught Dynamics, Kinematics & Machine Dynamics, and Heat Transfer during his career at BSU. In addition to the teaching experiences outlined above, Khosrow taught System Dynamics and Control I & II, Machine Design, and Thermal-Fluids Science in his previous position as an instructor at Rowan University. He also instructed a graduate course on Computational Fluid Mechanics in Mechanical Engineering Department at Villanova University in the spring semester of 2017. Dr. Ebrahimi obtained his Ph.D. in Mechanical Engineering from Kansas State University(K-State) in 2012. Between 2012 and 2016, he worked as a post-doctoral research fellow, Computational Fluid Dynamics (CFD) consultant, and a Thermal-Fluids Laboratory Instructor in the Department of Mechanical Engineering at Villanova University.

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**MULTIPLE INTERACTIVE HANDS-ON APPLICATIONS IN STATICS (5-minute demonstration)**

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ABSTRACT

This paper describes a moveable table that is recently developed at Minnesota State Mankato workshops. The table is developed to demonstrate several interactive hands-on applications in statics course for undergraduate engineering students. The development of this table has just been completed. It is believed that the table can be used to demonstrate many 2D hands-on applications in statics subjects such as the equilibrium of a particle and the equilibrium of rigid bodies in 2D including springs, pulleys, ropes, and cables. Further development of the table is ongoing (Phase II) to expand the capability of the table to allow the demonstration of 3D hands-on applications. The table was primarily developed to improve the students' learning by engaging them in interactive and inquiry-based approaches. The students can apply forces in different units using hand-held force gauges, feel the applied forces, and observe the impact of the applied forces (amount and location) on the problem in hand by directly reading – in real-time – the various force gauges at other locations. The students will be able to compare the hand-calculated solutions with the measured results using the hand-held force gauges. The students' impression while using this table was fabulous and it was believed that the demonstrations were very engaging (visually and physically) and important in understanding the subject. The students commented that this is "a great method of learning in class", "great activity" and "it would be fun to have a couple of different types of setups to analyze". More than 50% of the students indicated that this hands-on application improved their learning experience. Most of the students (more than 80%) would like to use the table in similar hands-on applications in statics.

## MULTIPLE INTERACTIVE HANDS-ON APPLICATIONS IN STATICS

## INTRODUCTION

[1] Stated that "Learning is a process whereby knowledge is created through the transformation of experience". According to this perspective, the two critical components of the learning process are (1) grasping through feeling and thinking (i.e., concrete experience and abstract conceptualization), and (2) transforming through doing and watching (i.e., active experimentation and reflective observation). The complete adaptive learning process requires these two critical components. When the students are actively engaged through these learning modes, their high-order skills are significantly improved [1], [2].

Statics is a sophomore-level course required by most engineering majors at universities. Solving problems in this course is critical for engineers. It is quite challenging for many students to relate what is covered in class to how particles in structural systems behave, especially if they do not have a good grasp of the concepts. It is then essential for instructors to know what common misconceptions students have and how to correct them. [3] Studied various teaching approaches to deal with students' misunderstandings in physics. He suggested a good starting point for instructions by focusing on prior knowledge which agrees with accepted theory. The visual component of classroom demonstrations allows students to capture and remember physical phenomena more effectively [4]. Several studies showed that demonstrations are very important in science and engineering education [5, 6, 7, 8]. However, several studies suggested that simply observing a demonstration may not be effective in students' learning [9, 10]. [11] and [12] showed that the effect of a demonstration on learning can be improved by increasing student engagement compared to only observing demonstrations. [13] showed how active learning is more effective than traditional learning in STEM courses. Several studies have been conducted on demonstrations for engineering courses. [14] and [15] presented several exciting and engaging demonstrations that make concepts easier to understand. [16, 17, 18, 19] developed engaging hands-on demonstrations on statics that make several fundamental concepts more graspable. The authors attempted to create an experimental hands-on application for the equilibrium of a particle in 2D – which is one of the topics covered in the statics course – that incorporated critical components of student learning such as grasping and transforming experience.

## DESCRIPTION OF THE HANDS-ON APPLICATION

Figure 1 shows the developed table to be utilized in statics course for hands-on applications. This table was developed at the Minnesota State Mankato workshops. The heavy-duty moveable table was used to carry three steel frames (36 in. width by 30 in. high) 5 in. apart. The frames were connected to two steel bars at the top and were connected to approximately 150 lb granite stone at the bottom. The top bars and the bottom stone allowed the frame to be rigid enough against applied loads in our application. Holes were made through the steel frames at 1-inch intervals on the center to allow us to attach elements to the frames through several handy steel pushpins.

Figure 1. Developed moveable table for hands-on application in statics

The moveable table was primarily developed to allow statics instructors to use it in their classes for the demonstration of various concepts in statics such as equilibrium of particles and rigid bodies in 2D and 3D. Although the table was developed for statics, dynamics and mechanics instructors expressed interest in utilizing the table for classroom demonstrations. The development of this table was just completed a few months ago. It was used to demonstrate the equilibrium of a particle in 2D.

DESCRIPTION OF THE EXPERIMENTAL HANDS-ON APPLICATION

After students learned about the theoretical concepts of equilibrium of particles in 2D, the students were asked to conduct a hands-on application to experience a real problem that they can see and touch. Details of the hands-on activity can be found in the appendix. Figure 2 shows the actual setup of the hands-on application which involves a steel cable and a spring connected o the frame from one side and connected together with a steel ring. A deadweight (W) is attached to the steel ring which made the spring elongate. To carry out this activity, the students were divided into groups of 2 so they can help each other and discuss their results with the instructor. Each group applied two random weights (W) to the steel ring. Once the system reached equilibrium (spring elongated/stretched to carry its share of the weight (W) and the entire system stopped oscillating), the students were asked to read the tension in the steel cable from the force gauge. Also, the students were asked to read the angles of the steel cable with the frame and the spring with the frame using a digital angle finder (shown in Figure 2). Finally, the students were asked to measure the elongated/stretched length of the spring at equilibrium. The students had to compare the results obtained from hand calculations and real measurements.

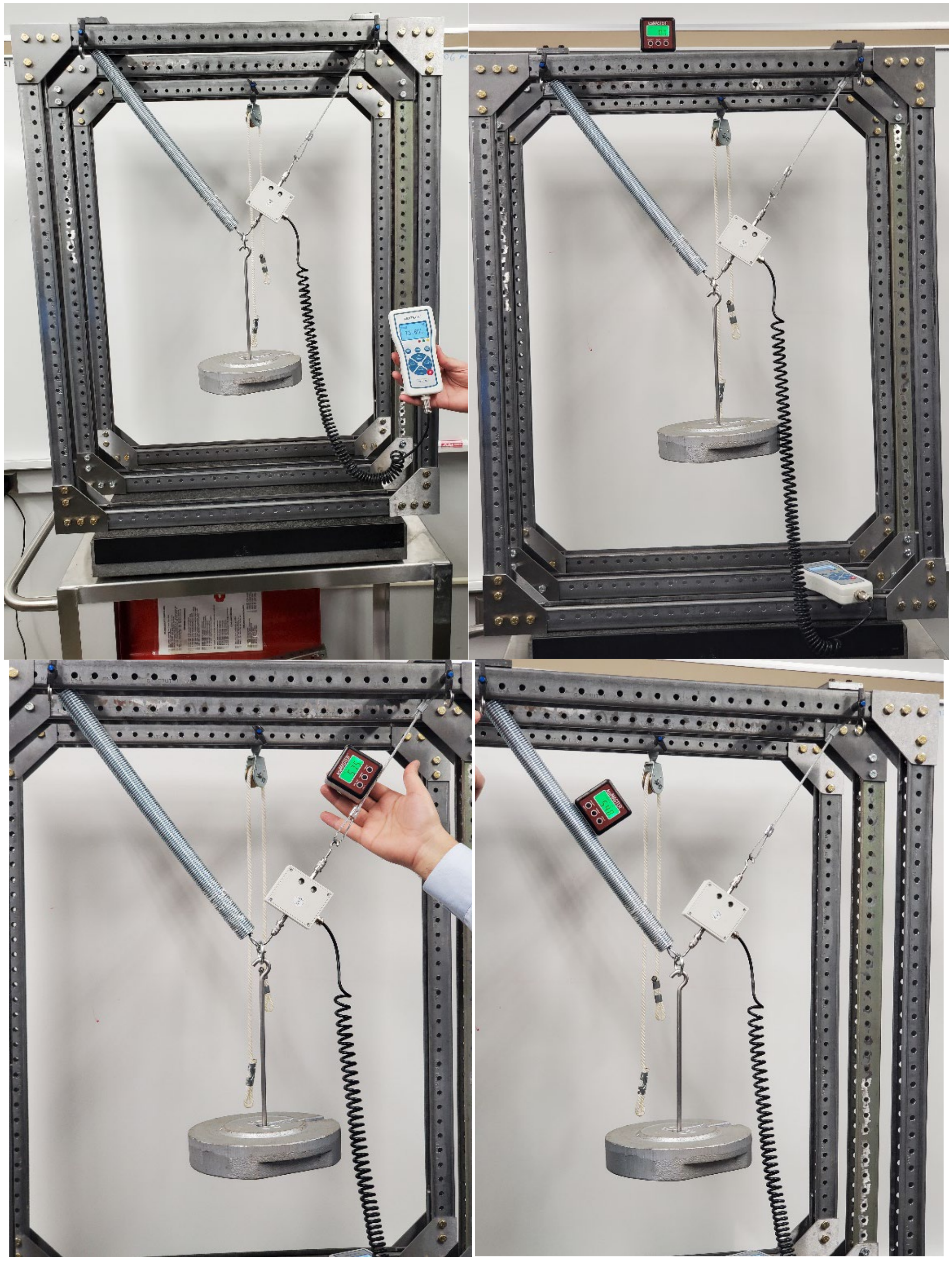

Figure 2. The physical model of the hands-on application

## STUDENT PERCEPTIONS

After the students had the opportunity to carry out the experiment and engage in discussion with their peers and instructor, they were asked to fill out a survey about their perceptions. The survey included the following questions:

Q1. Did the experiment improve your understanding of the equilibrium of a particle in 2D?

Q2. Would you like to conduct similar hands-on applications in other topics in statics?

Q3. Did you find the instructions given by the instructors useful in running the experiment?

Q4. Did the measured values verify your hand-calculated values?

After the data analysis (n = 15 students), at least 50% of the students felt that this hands-on application improved their learning experience as shown in Figure 3. On the other hand, more than 80% of the students, as seen in Figure 4, expressed their desire to see similar hands-on applications in other topics in statics. While conducting the experiment, the instructor assisted the students, answered their questions, and discussed ideas with them. This student-instructor discussion was valuable as more than 80% of the students indicated that it was a useful discussion as shown in Figure 5. Also, students were able to verify the hand calculations based on the learned theoretical concepts with the measured ones. They were able to see that there are some differences due to measurement errors with the various devices used (angle finder, force gauge, and ruler). More than 60% of the students (Figure 6) felt that the measured results either perfectly or closely agree with the theoretical hand calculations. The students have provided several suggestions to improve the experiment in the future such as: giving each group more time to conduct the experiment (some groups felt rushed) and using flat cardboard to support the back of the digital angle finder when unstable to reduce the influence of hand pressure. It was encouraging to see comments from students such as very clear instructions, very well-planned experiment, well-designed and executed, great visuals of the material in class, and a great method of learning in class would love to have a couple of different types of setups to analyze such as pulleys, and great activity.

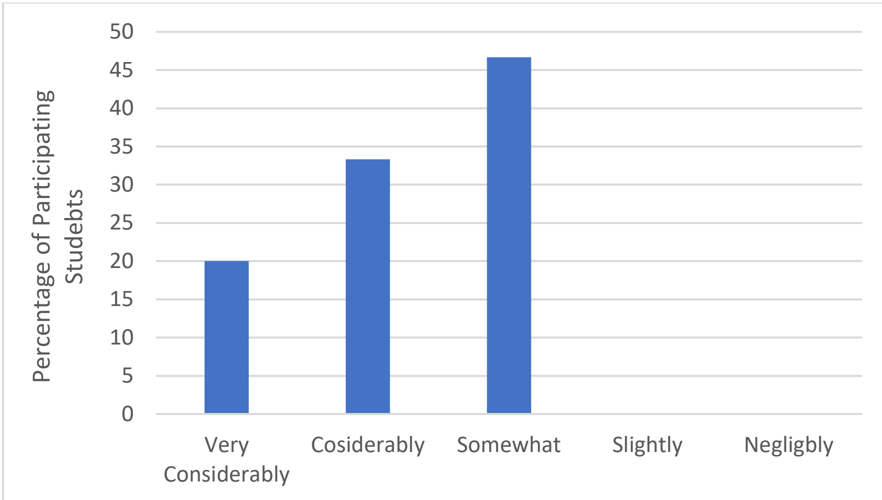


Figure 3. Students' responses to Q1

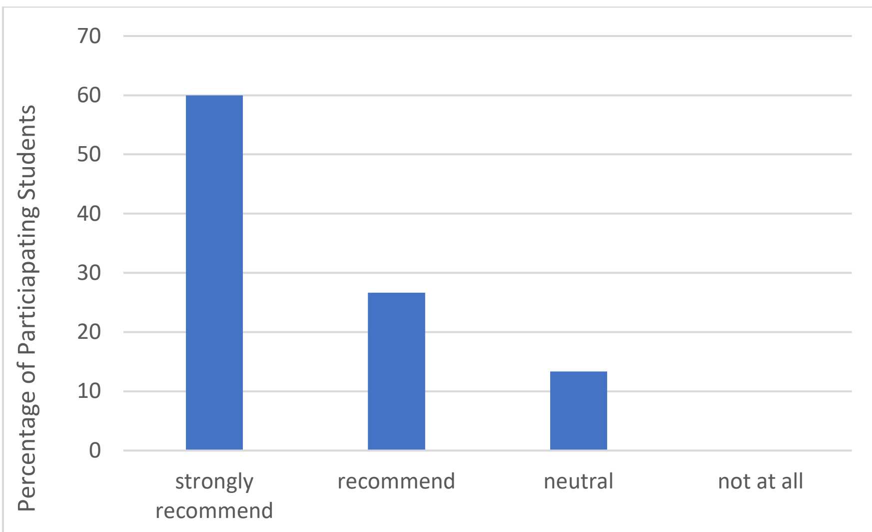


Figure 4. Students' responses to Q2

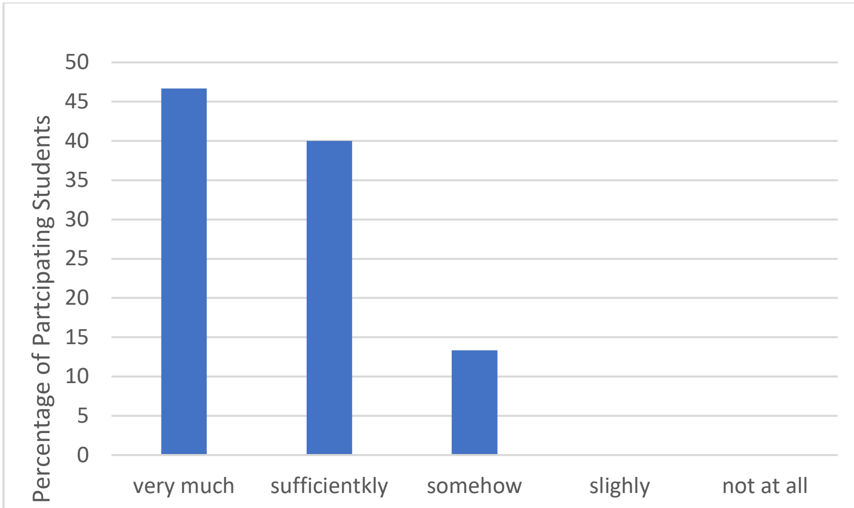


Figure 5. Students' responses to Q3

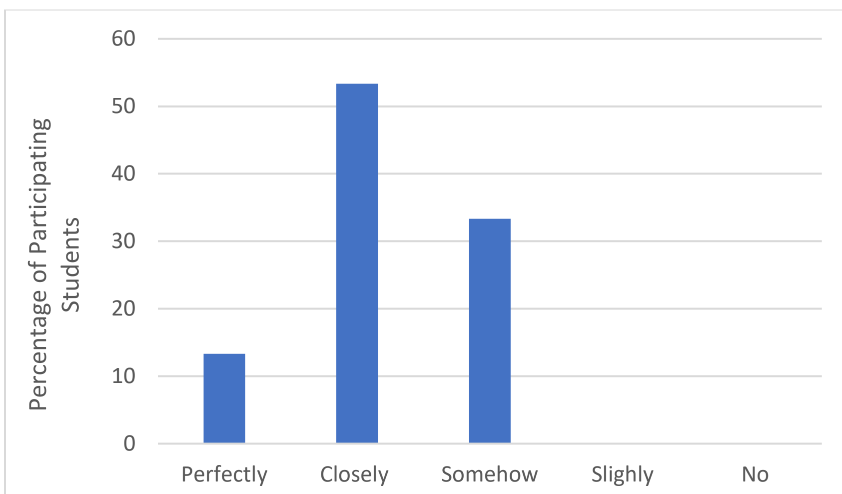


Figure 6. Students' responses to Q4

## HANDS-ON APPLICATIONS FOR FUTURE CLASSROOM DEMONSTRATIONS

As mentioned earlier, the table was developed for multiple interactive hands-on applications in statics. The authors were a little rushed because they just finished the development process, and the assessment of student learning could have been more thoughtful and detailed. But the authors were excited to share this table with the ASEE community in Minneapolis as part of the best in 5 minutes demonstration sessions. The authors have several future plans to develop different hands-on applications to make critical topics in statics more perceivable to students and create durable learning. Some of the hands-on applications are equilibrium of rigid bodies in 2D (Figure 7), equilibrium of systems with pulleys (Figure 8), and equilibrium of triangular/rectangular plates in 3D (Figure 9).

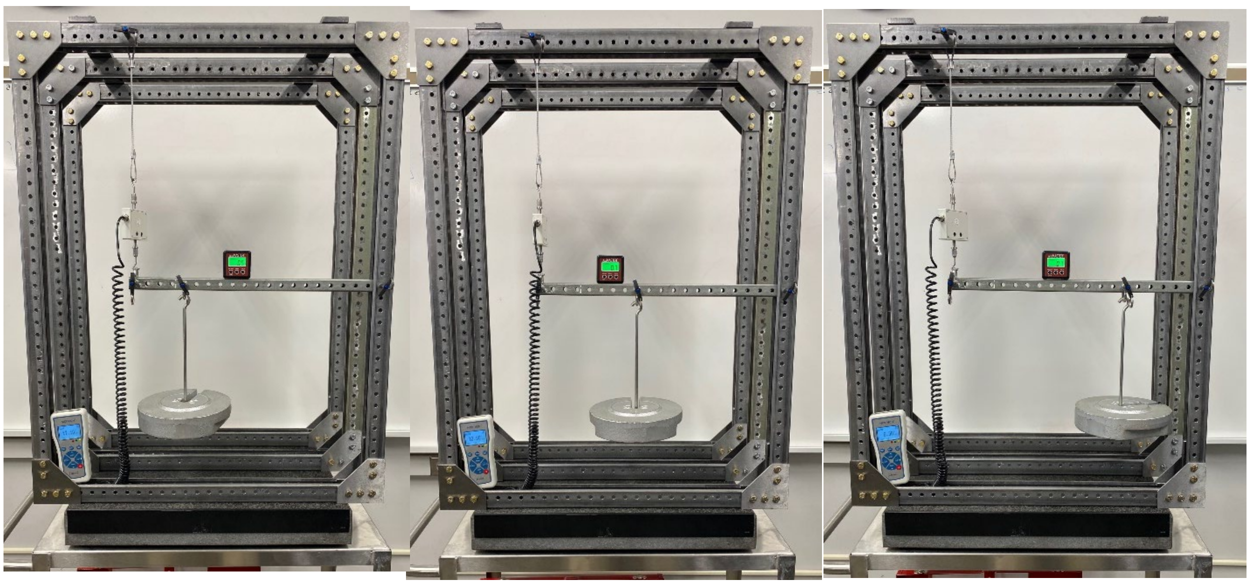

Figure 7. Example of hands-on application for the equilibrium of rigid bodies in 2D

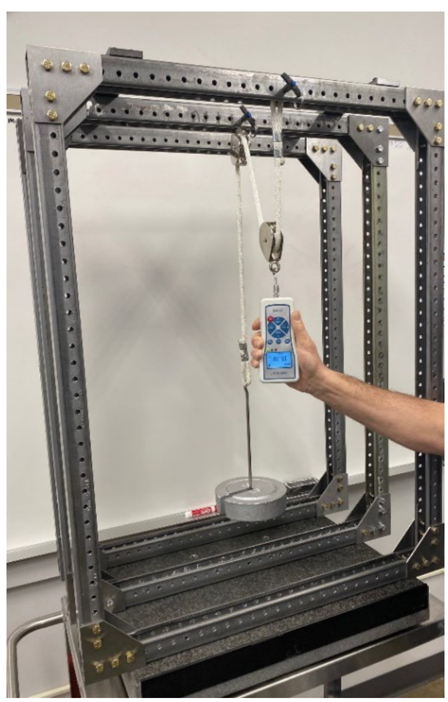

Figure 8. Example of hands-on application for the equilibrium of pulley assembly

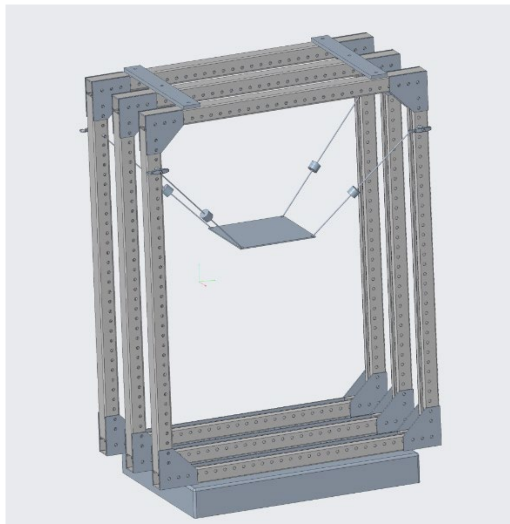

Figure 9. Example of future hands-on application model for the equilibrium of plates in 3D

SUMMARY

A moveable table was developed at Minnesota State Mankato workshops to allow statics instructors to use it in the classroom for demonstration purposes. In this paper, a hands-on application was developed using the table to demonstrate the equilibrium of a particle for 15 undergraduate civil and mechanical engineering students. Students were divided into groups and were asked to measure the actual forces, lengths, and angles in the system. Then, the measurements were compared with the hand calculations based on the learned theory. All the students were involved in conducting the experiment. Most of the students were able to verify the theoretical and measured results and explain the various sources of errors in measurements. Also, most of the students indicated their wish to see similar hands-on applications in other topics in statics.

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