USING A MOLA STRUCTURAL KIT TO TEACH TRUSS BEHAVIOR

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Resumo: *This complete evidence-based practice paper will describe an innovative experience in truss teaching. How do flat trusses work? How do tensile and compressive forces behave in a structure? The trusses subject is addressed during the first year of the Engineering course of the Maua Institute of Technology and is the basis for further use mainly by the Civil Engineering course. For proper use in class, it was necessary initially to present a simpler situation that would allow the student to build the knowledge necessary to work with a more complex case, in which several concepts are mobilized at the same time. Students, through modeling and experimental verification could test concepts and obtain answers to the behaviors studied. The innovation here was the use of a Mola Structural kit, an interactive physical model that simulates the behavior of architectural structures. Thus, by means of the usage of Mola Structural kit (https://molamodel.com/), students set up several simple structures and increased their complexity, analyzing at each step the involved concepts. Then, they performed the physical-mathematical analysis applying the knowledge of Free Body Diagram and Force Balance, modeling the problem, and then comparing the result obtained with a prototype built by the Physics student monitors. The activity was applied at the last semester of the 2018 school year to 1st year engineering students during the Physics lab classes. The attraction for the kit was almost immediate. Because easy interaction, many students already wanted to start practicing before to listen to initial explanations. The spatial visualization was of great value so that the students could understand more clearly the concepts of tension and compression forces involved and verify in a practical way the studied knowledge. According to a questionnaire applied to students, it was found that the understanding of flat trusses was better with the use of the kit for 74.4% of students, and the concepts* *of tension and compression became very clear for a 100% of student. That the physics classes contributed positively to the understanding of future subjects (74.4% answered yes and reasonably) and that the understanding of the joint method of obtaining internal forces was clear to 84.6% of the students.*

Palavras-chave: *Truss;Physics*

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1 INTRODUCTION

Statics is a general undergraduate engineering course commonly enrolled by students in their sophomore year and is part of the engineering curriculum for civil and mechanical engineering programs. A truss consists of three or more members connected by pin joints in a triangular configuration. Trusses are found in many common structures such as bridges and buildings (Figure 1).

Figure 1: Truss applications - Bridge in Finland / Bus Terminal in São Paulo - Brazil

The truss is a fundamental design element in engineering structures and it is important that students develop a correct understanding of this device. Trusses can be analyzed using simple Newtonian mechanics. The inclusion of a truss example in a physics, or statics course presents an opportunity to illustrate an application of particular interest to the engineering students in the class. The theoretical determination of the forces in the members of the truss is done by assuming that each member of the truss is in static equilibrium. Usually, the adopted free body diagram of the truss neglects the weight of the members. Since the truss members are straight structural elements in either tension or compression, all forces acting on each joint can be considered coplanar forces acting directly on the pin. There is no net torque about the pin. Force equilibrium can be determined from $\sum F_x=0$ and $\sum F_y=0$. This set of assumptions is termed the method of joints (BEER, JOHNSTON, 1988). By setting up a force balance for each joint, a relationship between the force F applied at some spot of the truss and the force in others member can be derived.

Many papers used to measure forces in truss by some apparatus (PINKERTON, et al., 2002), use exercises to enhanced statics lectures (YANG, WITHIAM, 2011), bridges contest (AKYURTLU, et al.,2015), (CRITTENDEN, et al., 2013), (TIMS, et al., 2011), concept inventory (ATILOLA, et al. 2012) or modeling kits (DAVISHAHL, et al., 2018).

While observing a real structure, it is difficult to visualize the physical phenomena involved in its behavior. Its deformations and displacements usually cannot be detected by the naked eye, making it a very abstract and difficult subject to understand.

Looking to an opportunity for students to compare theoretical predictions of truss behavior with actual performance in a design context, Maua Institute of Technology decided to use Mola Structural kit (MOLA STRUCTURAL KIT, 2018) and (MERIAM; KRAIGE; 2016). Mola Structural kit is an interactive physical model that simulates the behavior of architectural structures. The model consists of a set of modular pieces, allowing countless combinations. With Mola kit you can build different structural systems, visualize the movements and deformations of its elements and have a sensory experience with structural behavior using your own hands. The model requires no prior technical knowledge for you to start studying the structures. Its use is very simple and intuitive and is applicable to both professional and students, as well as anyone interested in the subject. Mola parts were designed with specific materials to allow the visualization of these phenomena. The idea is to simulate the behavior of structures in a tactile and visual way, making the subject more concrete and intuitive.

The Mola Structural Model is compact, versatile and easy to use. All parts are connected through magnetism, and each one represents one or more elements of a real structure, so a physical model representative of a three-dimensional Cartesian coordinate system structure allow students build, manipulate and analyze models of textbook style homework problems. Student groups use the kit to explore statics concepts through a series of exercises that connect typical mechanics analysis tasks such as sketching free-body diagrams, mathematical manipulations in vector notation,that students can explore to develop their conceptual knowledge.

This paper presents research on the effectiveness of the use of Mola Structural Model to assist students in understanding and learning concepts taught in the undergraduate Statics course. In 2018, Mola Structural Model was used in Physics Class, in 2019, in a new curriculum design, Mola Structural Model was applied in Engineering Fundamentals subject. Both subjects were developed to almost 1,000 first year students.

2 PROJECT APPROACH

Mola Structural Model was applied in a 100 minute laboratory class. Prior to the class, the student should watch the video and complete the lesson available on Moodlerooms: https://youtu.be/XvYgN_kPAEk.

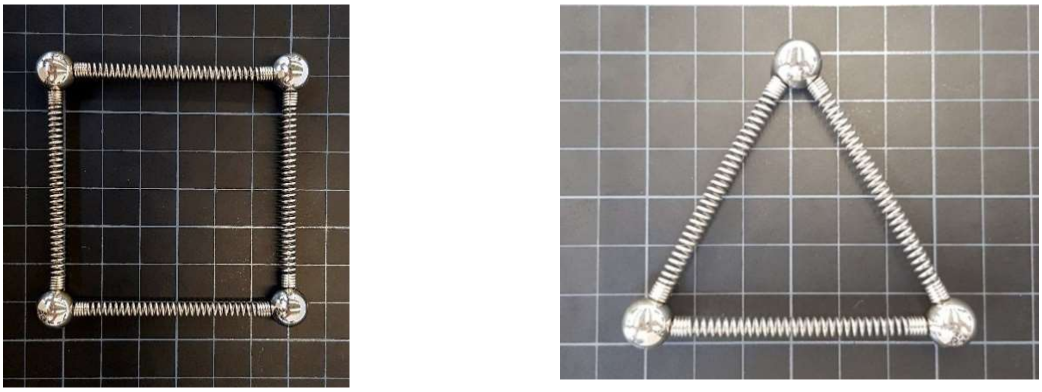
The objectives of the experiment were: to study loaded flat trusses and to study tensile and compressive forces. In class, the study was divided into three parts: Part I: Evaluating Stability and Studying Types of Support / Part II: Evaluating tension and compressive forces / Part III: Solving the proposed exercises.

Part I: Evaluating Stability and Studying Types of Support

In this part, using the kit, students must assemble a square as in Figure 2a), and apply a horizontal force to one of the joints. Observe what happens by checking whether the structure is stable or not. After, students must assemble a triangle like the one shown in figure 2b) and check it is more stable than square structure. After, in teams, students must discuss what causes the change in behavior and make Free Body Diagram - FDB of each one.

Figure 2: (a) Square and (b) Triangle structures to be assembled with the kit (MOLA STRUCTURAL KIT, 2018)

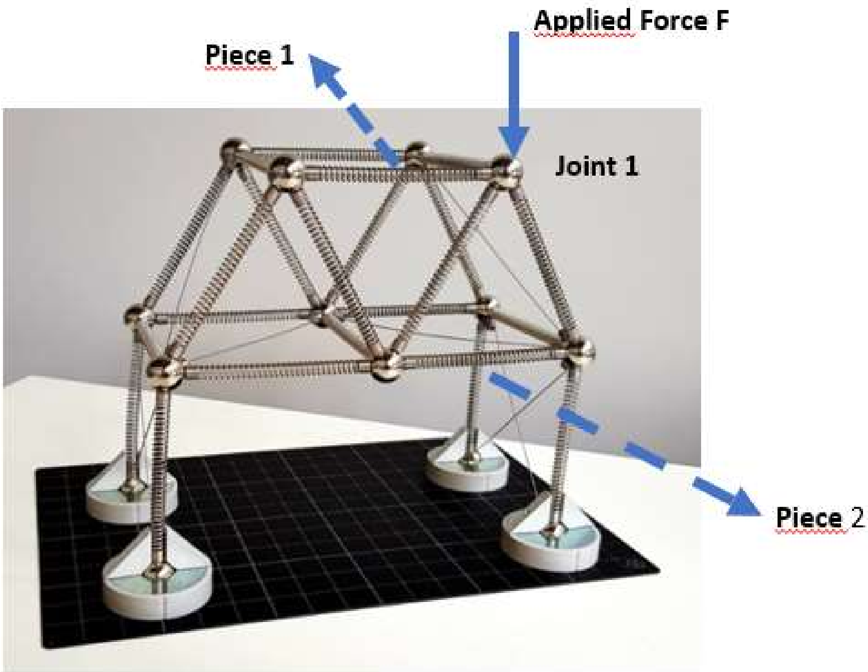
(a) (b)



Part II: Evaluating tensile and compressive forces.

The student should assemble a truss like the figure 3.

Figure 3: Truss to be assembled (MOLA STRUCTURAL KIT, 2018)



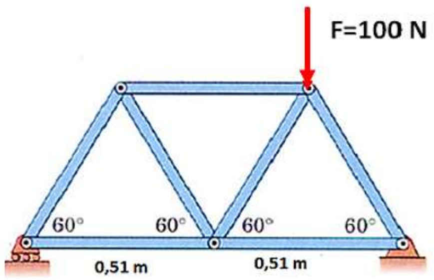
Students must:

a) Remove piece 1 shown in figure 3 and evaluate if this piece is experiencing compression or tension.
b) Remove piece 2 shown in figure 3, and apply a vertical force on indicated joint1. Evaluate what kind of force is applied over piece 2.

Part III: Solving proposed exercise

Using a similar truss (Figure 4), and ignoring the weight of the truss elements, the students were supposed to draw FBD and to calculate external and internal forces for each truss member by method of joints, classifying the last ones in tension or compression type of force.

Figure4: Truss exercise (MERIAM; KRAIGE; 2016)



3 RESULTS AND DISCUSSION

Initially, when preparing didactic material to teach Truss, teacher´s team found great difficulty how to work the concepts involved in Truss behavior such a way that the student himself built his knowledge and explored possibilities. In this sense, the acquisition of the didactic kit for truss construction was fundamental for this development. The kit allows exploring various types of constructions and concepts improving the spatial visualization of a theme that is often not so clear to students.

The activity was applied in 2018 to First Year Engineering students during Physics lab classes. The attraction to the kit is practically immediate. Because easy interaction, many students already wanted to start practicing before to listen to initial explanations. The spatial visualization was of great value so that the students could understand more clearly the concepts of tension and compression forces involved and verify in a practical way the studied knowledge. To measure student´s perceptions a quiz using a Likert Scale was applied to the same students now in the 3rd year of Engineering Course. Table 1 summarizes the quiz results from 160 students responses.

Table 1. Student´s perception – quiz results

Question	Yes (%)	Satisfactory (%)	Very little (%)	No (%)
1) Was understanding of trusses behavior better with the use Mola kit?	74.4	20.5	5.1	-

2) In this activity, did you get a better comprehension about concepts of tension and compression forces?	100.0	-	-	-
3) Did you learn method of joints (BEER, JOHNSTON, 1988)?	84.6	12.8	2.6	-
4) Did those activities contribute positively to the understanding of future subjects?	46.2	28.2	20.5	5.1

It´s possible to see by the answers that using Mola kit was a right-point methodology to teach truss behavior because gets a great result in comprehension concepts.

Also, some qualitative student's perceptions get were:

"I could see the application of truss theory in practice."
"I would like to get one of it in my home."
"Now I can understand it."

4 FINAL CONSIDERATIONS

Student feedback on the modeling exercises indicates that the models and associated curriculum provide an engaging context for group discussion and problem solving. Students report their experience with the physical models increase their understanding of fundamental statics concepts such as free body diagrams, force moments and support models. Using Mola kit allow students get a better comprehension about concepts of tension and compression forces.

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Key-words: *Truss, Physics.*