The Construction of Force, Moment and Torque Diagrams of a Loaded Shaft in the Context of a Flipped Machine Design Classroom

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This paper presents the application of the principles of Flipped Classroom to the teaching of the construction of Force, Moment and Torque diagrams of a loaded shaft. Flipping the Classroom is a proposal in the context of Blended Learning which suggests that in-class students' activities, supported by learning material made available to them in advance, could replace the traditional scheme of teacher led lectures followed by homework. Trying to take advantage of the benefits of Blended Learning, we introduced a Flipped Classroom within a Machine Design course of the Mechanical Engineering Educators Curriculum.

Keywords: force moment and torque diagrams, blended learning, flipped classroom, machine design, ICT in higher education

INTRODUCTION

Every academic teacher is, more or less, concerned about the effectiveness of knowledge transfer to the students. In an engineering department, knowledge presents a great deal of complexity and differentiation as it may extend in many different disciplines (from mechanics to thermodynamics, from electronics to environmental impacts, from reliability to the organization of material resources etc.) Seeking the application of the Confucian educational principle "involve me and I will learn", the teacher of the future engineers constantly looks for ways to actively engage the student in the learning process, aiming at the consolidation of knowledge as well as at the development of skills, necessary for an engineer, such as critical thinking and creativity. In this sense, a mechanical engineering department curriculum is an ideal framework for the application and evaluation of the modern student-centred educational approaches and the use of educational technology. The need to effectively contain the basic methodology of the construction of Force, Moment and Torque diagrams of a loaded shaft into a short time frame was an ideal opportunity to apply the very promising Flipped Classroom method.

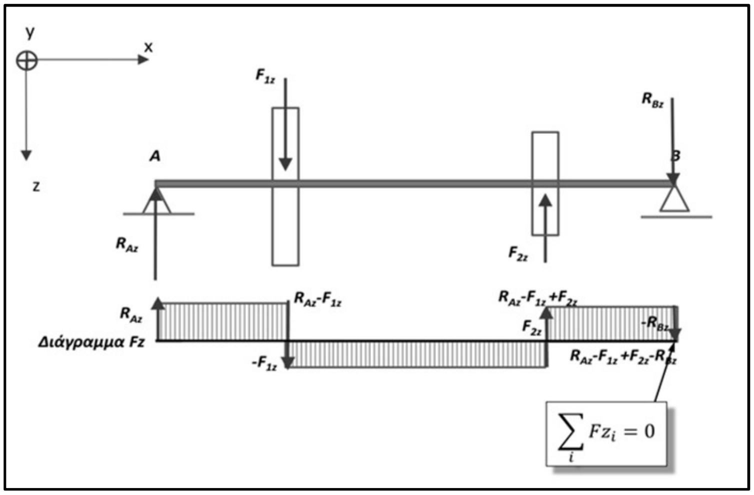
METHODOLOGY

Blended Learning, which combines on-line and face-to-face instruction (Reay, 2001, Sands, 2002, Young, 2002), has been recognized as more effective than purely face-to-face or purely on-line classes, thus resulting in substantial increase of students' academic achievement (Saritepeci & Çakir, 2015). Flipped Classroom is a dynamic variant of Blended Learning. It aims to provide students with valuable time for interacting with knowledge, peers and teachers through their active participation in appropriately selected brain-stimulating activities, which take place in the classroom. To make this possible, the necessary theoretical background is shifted off class and usually provided beforehand online. (Ronchetti, M., 2010, Strayer, 2012). It consists, mainly, of audiovisual educational material, videos and/or animation, accompanied by interactive tools like hypertexts or self-assessment quizzes. The development of such on-line material is a complex and demanding process and it is considered a major weakness of the method, since it takes a lot of time and it usually requires the use of significant human time and technical means. Luckily, due to the broad recognition of the method's important benefits, several tools have been made available, that can significantly reduce time, effort and cost of producing high-quality educational material. The construction of Force, Moment and Torque diagrams is an important step towards the mechanical design of a loaded shaft since by using them, the designer engineer may identify the shaft's critical sections and determine their appropriate dimensions. (Budynas–Nisbett, 2006). The theoretical knowledge, required for the diagrams construction, is not included normally in the Machine Design syllabus. Nevertheless, a lot of valuable course time has been often sacrificed to help students master the application of the method in real shafts that work in a 3D space and thus avoid a possible cognitive gap that prevents students to subsequently approach more advanced concepts effectively. Flipped Classroom seemed like a promising method to maximize the relation of learning outcomes versus the total course time dedicated to the method. The organization of the in-class activities is a key factor in the attempt to engage students with evidence-based practices that could significantly improve their learning outcomes. (Deslauriers et al., 2011) Out-of-class material should cover the necessary theory as well as provide the appropriate background for classroom activities. The extent of the on-line material and the off-class working time of the students should be kept to a moderate level so as not to discourage them.

Off-class Preparation

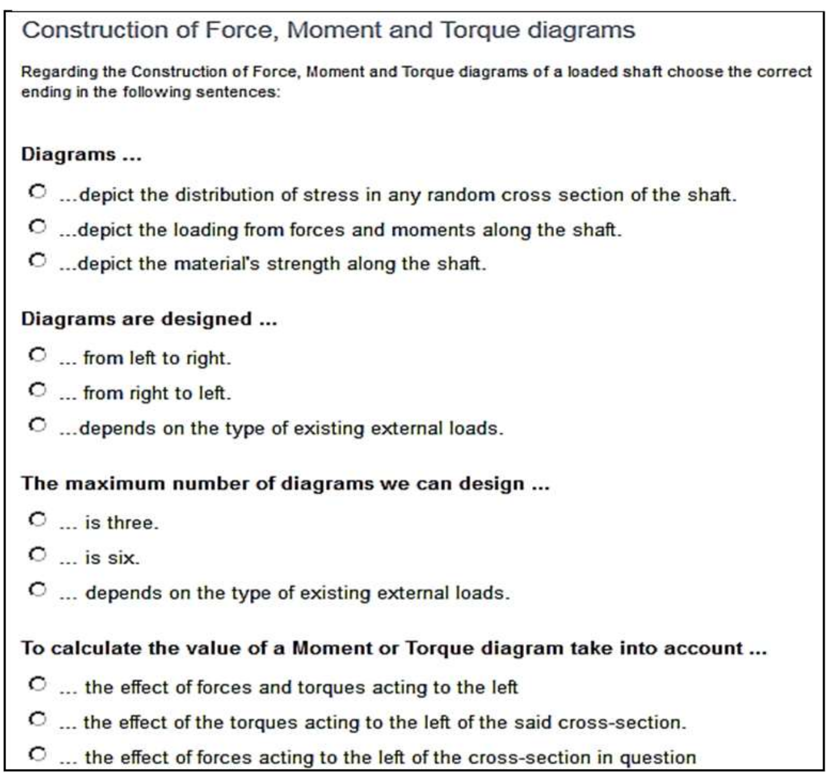
The total course was divided in two sections: the first concerning the construction of Normal and Shear Force Diagrams and the second, four days later, the construction of Moment and Torque Diagrams. The students, after a short introductory briefing, were invited via an automated e-class application, to attend the classes, which would be organized as a Flipped Classroom, on 11/10 at 13: 00-16: 00 and 15/10 at 09: 00-12: 00. The announcement contained a link to a hypertext called "Preparation Guide: the construction of Force, Moment and Torque diagrams of a loaded shaft in a Flipped Classroom". Links on the hypertext led to the on-line material, uploaded to Dropbox®. To get ready for classroom activities, the students should spend some time at home. The total duration of preparation for each of the above days were not expected to exceed 30 minutes and could be done whenever possible, continuously or even with intermissions. Preparation for the first day consisted of watching two video animations, with Greek narration and with 11:55 min total duration, on Axial Force Diagram Fx and on Shear Force Diagrams Fy and Fz. See Figure 1

FIGURE 1
SHEAR FORCE DIAGRAM F_Z



A tutorial in pdf format was also available to them with necessary definitions and examples. The students, then, were called to answer questions contained in two quizzes. See Figure 2, related to the knowledge provided in the immediately preceding videos. Quizzes serve two purposes: On one hand, they promote knowledge consolidation (Squire, 1986, Karpicke & Blunt, 2011). On the other hand, quizzes provide valuable and timely feedback to the teacher about the points of the on-line material that remained vague for the students, in order to clarify them in the classroom (Novak et al., 1999).

FIGURE 2
QUIZ 1


Construction of Force, Moment and Torque diagrams

Regarding the Construction of Force, Moment and Torque diagrams of a loaded shaft choose the correct ending in the following sentences:

Diagrams ...

- ...depict the distribution of stress in any random cross section of the shaft.
- ...depict the loading from forces and moments along the shaft.
- ...depict the material's strength along the shaft.

Diagrams are designed ...

- ... from left to right.
- ... from right to left.
- ...depends on the type of existing external loads.

The maximum number of diagrams we can design ...

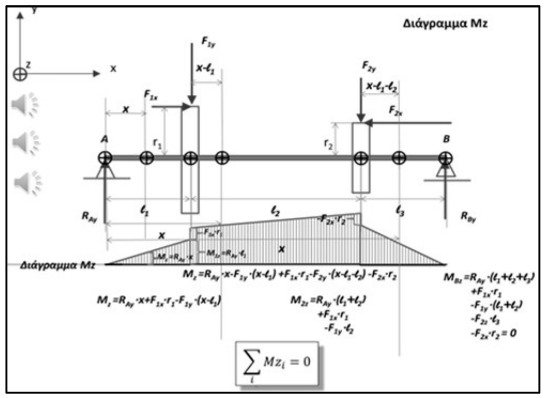
- ... is three.
- ... is six.
- ... depends on the type of existing external loads.

To calculate the value of a Moment or Torque diagram take into account ...

- ... the effect of forces and torques acting to the left
- ... the effect of the torques acting to the left of the said cross-section.
- ... the effect of forces acting to the left of the cross-section in question

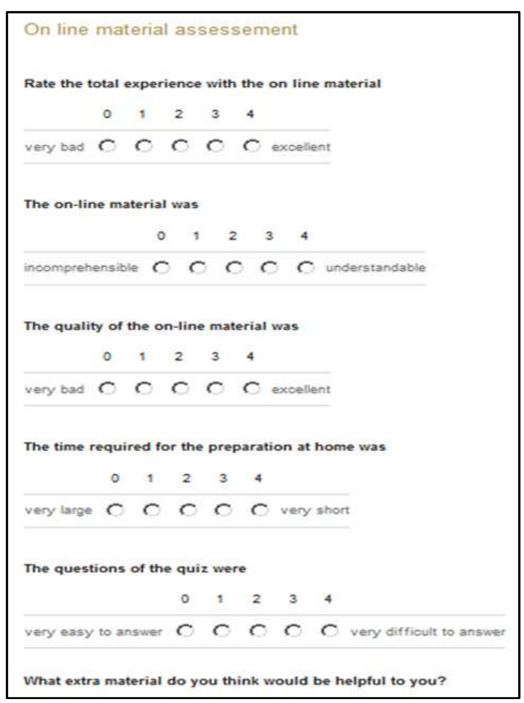
The quizzes have been created using Google® Forms and the students were redirected to them via links contained into the Preparation Guide hypertext. After being answered, they were submitted online and the teacher could either assess them individually or see a comprehensive report of class achievement. The preparation for the second day had a similar structure, consisting of watching two video animations, with Greek narration and with 13:04 min total duration, on Torque Diagram Mx or T and on Bending Moments Diagram My and Mz. See Figure 3.

FIGURE 3
BENDING MOMENTS DIAGRAM MZ



At the end of the off-class preparation for the second day, students were encouraged to evaluate the process and the on-line material, through a questionnaire. See Figure 4. The questionnaire contained questions with a linear-scale response and students were also given the opportunity to express their views, through a short paragraph.

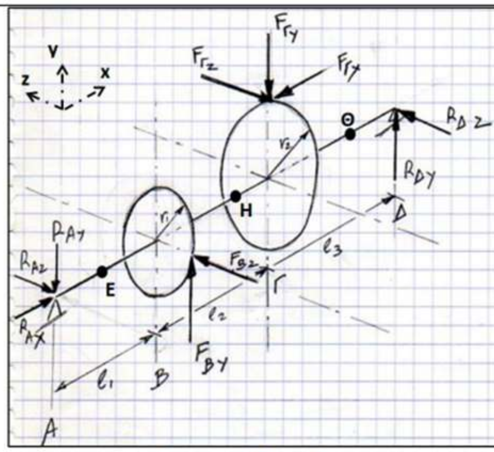
FIGURE 4
OFF-CLASS MATERIAL ASSESSMENT



In Class Activities

In both days, the in-class activities began with a review of the material, through an organized discussion. By a series of questions, posed by the instructor, students had the chance to retrieve and put forward the basic principles of the method in hand. Special attention was given to the points, which were characterized in the on-line quiz and questionnaire as more vague or obscure. Such structured and discretely steered discussions can help the instructor to evaluate student comprehension. Students by assuming a more active than usual attitude soon felt more confident and relaxed and started to enjoy the process. Students were divided into a number of “companies” to study specific problems and draw conclusions. The problems based on Jonassen's typology (Jonassen, 2010), such as logical, decision. (See Figure 5), design problems (See Figure 6) and debates, were specifically selected and aimed at deepening students' knowledge on specific aspects of the method and the related theory.

FIGURE 5
FIRST DAY. EXCERPT FROM AN IN-CLASS ACTIVITY

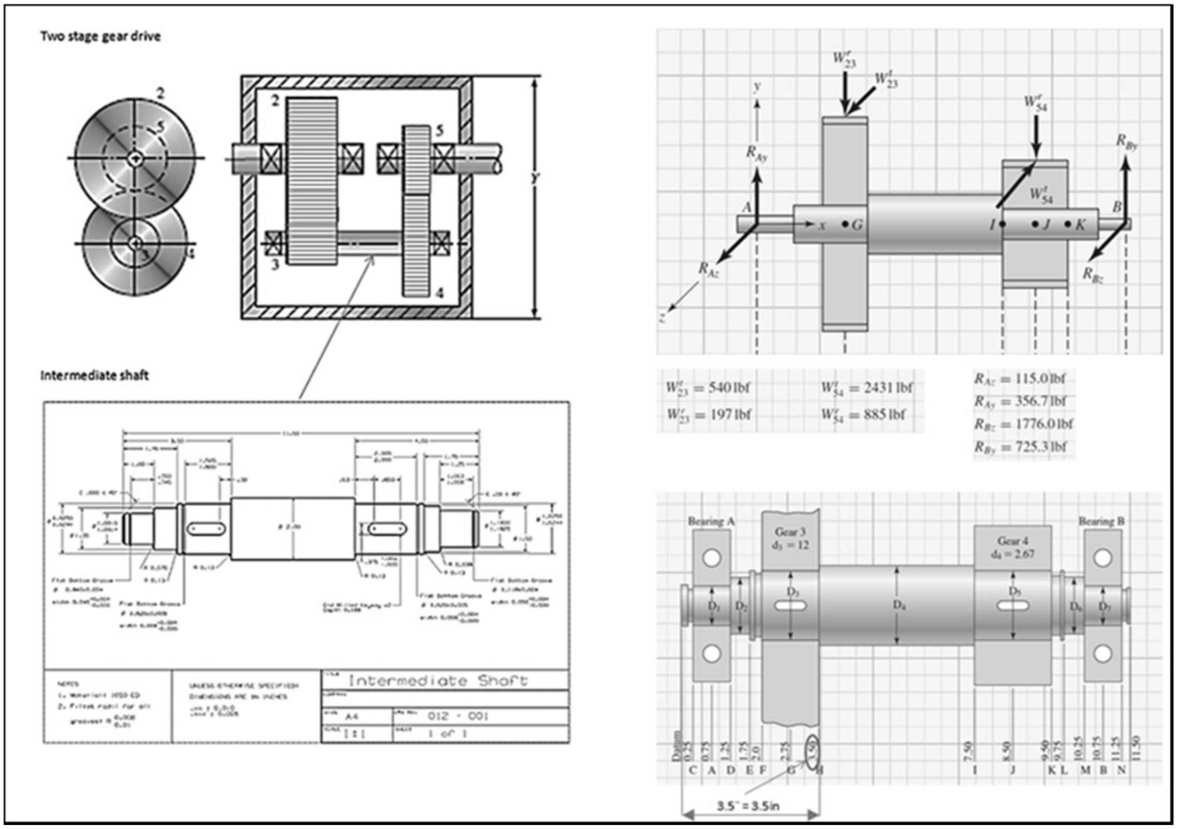


At the previous shaft, select by ticking next to the forces that influence the value of the diagram at the specific position.

Diagram Fz position H R_{Ax}☐ R_{Ay}☐ R_{Az}☐ F_{Bx}☐ F_{By}☐ F_{rx}☐ F_{ry}☐ F_{rz}☐ **none** ☐

During the last part of the second day’s in-class course, we dealt with the evaluation of in-class activities. The students had the opportunity to express their views on Flipped Classroom, which, in their vast majority, were very positive.

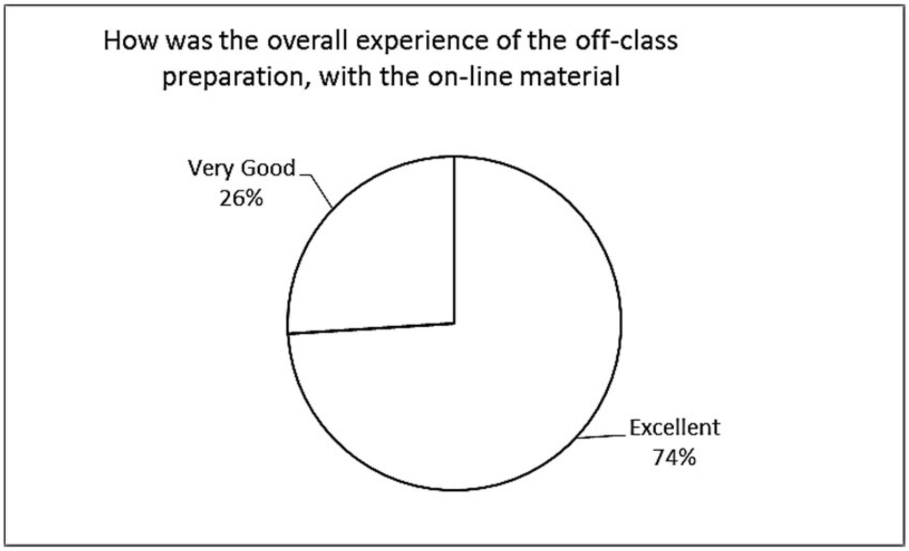
FIGURE 6
SECOND DAY. EXAMPLE FROM THE 4TH IN-CLASS ACTIVITY. DIAGRAMS OF THE INTERMEDIATE SHAFT OF A TWO-STAGE GEAR DRIVE



RESULTS

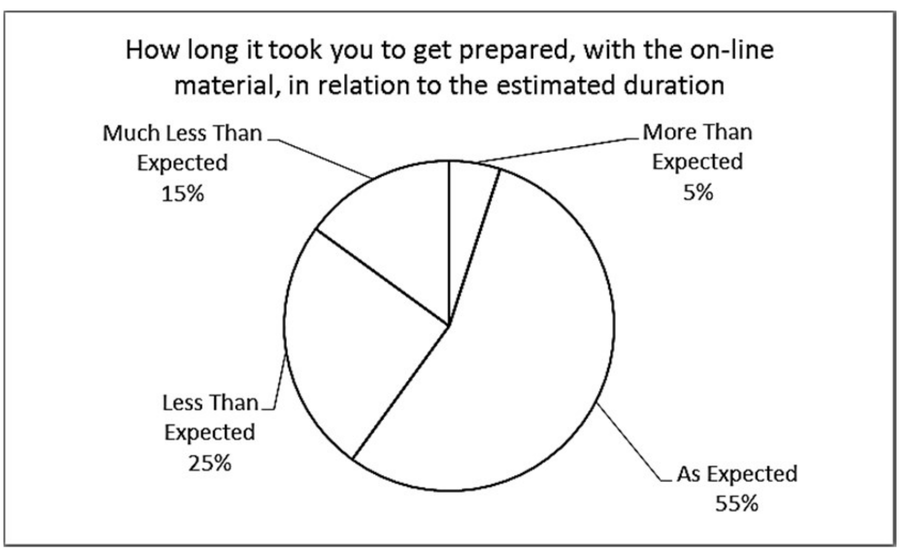
The results of the application of the method were very satisfactory. Participation, 62% in off-class preparation and 75% in in-class activities, exceeded all expectations. Although only 6 hours of the course time were consumed, the educational goal, e.g. to reach a significant level of student involvement into serious and demanding problems related to the construction of Force, Moment and Torque diagrams, was achieved. Students had two opportunities to evaluate the program: At the end of the off-class preparation eighty two percent (80%) of the participating students filled the assessment form. According to their answers, the off-class preparation was a positive experience to the students. To the question: “How was the overall experience of the off-class preparation, with the on-line material”, 74% of the participating students answered “Excellent” and 26% answered “Very Good”. See Figure 7.

FIGURE 7
OFF-LINE MATERIAL ASSESSMENT



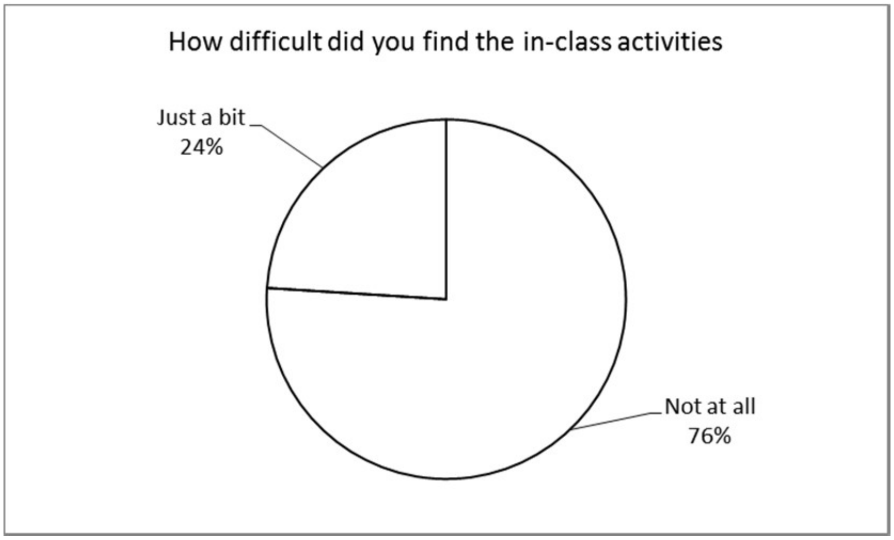
It, also, seems that the preparation was not time consuming. To the question: "How long it took you to get prepared, with the on-line material, in relation to the estimated duration?", 55% of the participating students answered "As Expected", 25% answered "Less Than Expected", 15% answered "Much Less Than Expected" and 5% answered "More Than Expected". See Figure 8.

FIGURE 8
OFF-CLASS PREPARATION TIME ASSESSMENT



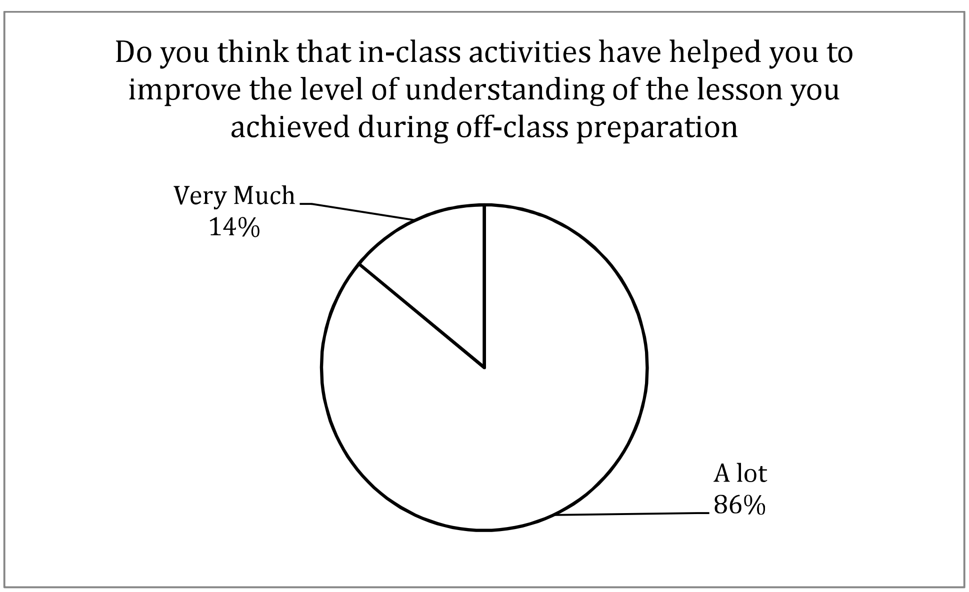
At the end of the in-class activities, to the question: "How difficult did you find the in-class activities?" 76% of the participating students answered "Not at all", and 24% answered "Just a Bit". See Figure 9.

FIGURE 9
IN-CLASS ACTIVITIES ASSESSMENT



To the question: "Do you think that in-class activities have helped you to improve the level of understanding of the lesson you achieved during off-class preparation?" 86% of the participating students answered "A lot" and 14% answered "Very much". See Figure 10.

FIGURE 10
IN-CLASS ACTIVITIES' UTILITY ASSESSMENT



CONCLUSIONS

In this research we explored the flipped classroom model for the presentation of the "Construction of Force, Moment and Torque Diagrams" in undergraduate mechanical engineering students. Actually, initial results provide evidence for the effectiveness of the method as well as its power to motivate and involve students, thus substantially improving their will and ability to learn. Moreover, an evaluation, based on qualitative assessments of class characteristics, such as participation and interest shown, in relation to the corresponding characteristics of a traditional teaching, was possible and impressive improvement was observed. Further investigation needs the determination of the type of problems that can effectively support in-class activities based on the lesson subject.

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