Serbian Tribology Society

SERBIATRIB '19

16th International Conference on Tribology

Faculty of Engineering University of Kragujevac

Kragujevac, Serbia, 15 – 17 May 2019

A TRIBOLOGY FLIPPED CLASSROOM: AN INTRODUCTION OF TRIBOLOGY BASIC CONCEPTS IN THE CONTEXT OF A BLENDED LEARNING MACHINE DESIGN COURSE

Pavlos ZALIMIDIS[1], Kyparissia PAPANICOLAOU[2], Nikolaos VAXEVANIDIS[3]

[1]Machine Design Laboratory (MaDLaB), School of Pedagogical and Technological Education (ASPETE), Greece, *Corresponding author: e-mail pzalimidis@aspete.gr

[2]Laboratory of Distance Learning with Digital Technologies, Department of Education, School of Pedagogical and Technological Education, (ASPETE), Greece, kpapanikolaou@aspete.gr

[3] Laboratory of Manufacturing Processes and Machine Tools (LMProMaT), School of Pedagogical and Technological Education (ASPETE), Greece, vaxev@aspete.gr

Abstract: *This paper presents the application of the principles of Blended Learning to the teaching of the concepts of Tribology. Blended Learning is a fast developing approach towards the direction of transforming teaching of engineering courses by actively involving students into the learning process and thus reportedly resulting in higher levels of student achievement than purely face-to-face or purely online classes. 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 Tribology Flipped Classroom within a Machine Design course of the Mechanical Engineering Educators Curriculum. The lesson was planned following established design principles. The content was divided in (a): The preparation material which was mainly pre-existing resources including video, notes, slides, taking into account the difficulties that students face on the topic as well self-assessment tests; all these being available on-line. (b): In-class activities including a variety of problems such as, decision and design problems, logical exercises, and debates. In class students worked individually and in groups, participating also in a peer review activity. The evaluation of the project revealed a quite positive view of the participating students on the flipped classroom approach, in comparison to the traditional lectures which they have attended.*

Keywords: *Tribology; blended learning; flipped classroom; machine design; ICT in higher education.*

1. INTRODUCTION

Apart from being scientists and researchers, we are primarily teachers, responsible for the effective transmission of knowledge to our future colleagues. A plethora of diverse topics, contained in the curriculum of an engineering department, impose the use of increasingly efficient learning approaches and, of course, the widespread use of available technology. Modern educational methods should be implemented and their characteristics, in particular their effectiveness in the teaching of technological subjects, should be evaluated in the classroom. Problem-based learning, Project-based learning, Blended Learning are among many of the contemporary approaches that are proposed as alternatives to traditional teaching, and a number of advantages as well as some drawbacks have been associated to each one of them. The need to present the basic principles of Tribology in a short time frame was an ideal opportunity to apply the very promising Flipped Classroom method. After a review of the methodology, in section 2, containing also a brief presentation of the specific objectives of the project, a detailed presentation of the two phases of the method follows, i.e. the preparatory activities outside the classroom, in section 3, and the activities in the classroom, in section 4.

2. METHODOLOGY

Flipped Classroom is an instructional approach and a type of Blended Learning that reverses the traditional, lecture based, learning setting, by delivering instructional content, outside of the classroom and, thus, freeing teaching time for brain-stimulating and student-engaging activities, in the classroom.

Blended Learning had been identified, by the American Society for Training and Development, as one of the top ten emerging educational trends (cited in [1]). Blended Learning, being a way of combining instructional modalities [2, 3, 4, 5], instructional methods [6], or, simply, combining online and face-to-face instruction [7, 8, 9], has been proven more effective than purely face-to-face or purely online classes. Indeed, different implementation cases of Blended Learning resulted in meaningful increase in student engagement and academic achievement [10] In particular, experiments on the Flipped Classroom concept, showed that the replacement of live lectures with online lectures and other on-line material, followed by enriched, learner-engaging, in-class activities significantly enhanced the usefulness, convenience, and value of the course for the majority of students [11,12].

A drawback of Flipped Classroom and Blended Learning in general is that it takes a lot of time and effort to prepare the on-line material. The creation of audio-visual, educational material is a complex and demanding activity that requires the use of significant human time and often the provision of special technical means. The cost of all these may, also, be substantial. A solution to the problem could be to film lectures. Sadly, this often results in low-quality videos that are not attractive to students, and thus have little ability to induce and maintain their attention at an adequate level. Fortunately, due to the broad recognition of the important benefits of this method and also the digital progress in general, several tools, that can facilitate the creation and processing of high-quality educational material, are now available. Animation software, video editors, compilation and subtitling tools, voice production, etc., can significantly reduce the time, effort and cost of producing the material and give it high, almost professional quality.

In order to apply the Flipped Classroom principles and evaluate said advantages, we decided to implement a course referring to the basic principles of Tribology and in particular to Lubrication, an important issue, most relevant to the syllabus of Machine Design.

Tribology and Lubrication are not included in the curriculum of the Department of Educational Mechanical Engineering; neither as a separate lesson nor as part of a course. Specific concepts, such as surface roughness, Hertz pressure, friction loss, are fragmentarily presented, or simply referred to, in the context of lessons such as Chemistry, Manufacturing, and Machine Design. It is up to the student to combine this knowledge in order to obtain a comprehensive understanding of e.g. how friction is created in the machinery, how the adverse effects of this phenomenon are reduced by Lubrication and how the properties of Lubricants influence this process. Since all this requires a hands-on experience rather than a purely theoretical presentation, the above-mentioned desired result is usually achieved, by the student, later in practice.

The implementation of a Flipped Classroom seemed like a promising method to overcome the unavailability of time in the normal program and, at the same time, to maximize the learning outcomes associated with Friction and Lubrication. Another similar lesson [13, 14], which took place during a previous academic year, gave us a useful starting point for the design of the course: A key factor is the proper organization of the in-class activities in order to engage students with evidence-based practices that could significantly improve their learning outcomes. [15].

Out-of-class material should be designed in such a way as to cover the necessary theory as well as to provide the appropriate cognitive background for the implementation of classroom activities. It is imperative to control the extent of the on-line material and to assure that off-class working time of the students will be kept to a moderate level so as not to discourage them.

3. OFF-CLASS PREPARATION

The students were given a short introductory briefing four days before the in-class activity course, providing them with necessary guidance and practical information concerning the method of flipped classroom. They were also told to “keep an eye” for a relative announcement.

After that, they were invited via an automated e-class application, to attend a seminar on "Friction and Lubrication" which would be organized as a Flipped Classroom. The announcement, which was texted to them, contained a link to a hypertext called “Preparation Guide: Friction-Lubrication in Machinery in a Flipped Classroom”. Links on the hypertext led to on-line material, uploaded to Dropbox®.

The on-line material consists of a number of short videos with English narration. Most Greek students are fluent in English, however, Greek close captions were provided because the videos contained several technical terms, related to Tribology, which are not familiar to the students. Only freeware was used to prepare the on-line material. Videos were edited using YouTube Studio® (beta) and subtitled using Google’s Creator Studio Classic®. There are also a number of text readings in Greek.

The total duration of all the videos was 16:52 minutes. Considering that 40-50% of students would like to watch once again the videos and that they would spend about 10-15 minutes, reading the texts and responding to the quiz and evaluation, students were given an a total duration estimate of about 40 minutes.

The on-line material was divided in three sections. The first section was about basic concepts on friction, lubrication and lubricants. It aimed to provide a brief and comprehensive view of the various forms of friction and how they are dealt with by the different types of lubrication as well as what are the main categories of lubricants. The second section was about the properties of the lubricants, their effect to machine lubrication and the selection of lubricants based on the machine operation. The third and last section was about lubricants classification and standardization and also lubrication tooling and equipment.

After each of the first two sections, the students answered a small number of questions, in a quiz, related to the knowledge provided in the immediately preceding section. Quizzes were used because they can serve two purposes: On one hand, they can induce immediate "activation" of the recently acquired knowledge and, therefore promote its consolidation [16, 17]. On the other hand, quizzes can provide 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 [18]. Quizzes were created using the Blank-Quiz template of Google Forms®, which simplifies questionnaire creation by choosing from a bunch of question options, from multiple-choice and dropdown menus to linear-scale rating, enriching them with pictures and video clips.

At the end of the off-class preparation, students were encouraged to evaluate the process and the on-line material, through a questionnaire. The questionnaire contained questions with a linear-scale response and students were also given the opportunity to express some views through a short paragraph. Eighty two percent (82%) of the participating students (19 people) 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”, 79% of the participating students answered “Excellent” and 21% answered “Very Good”.

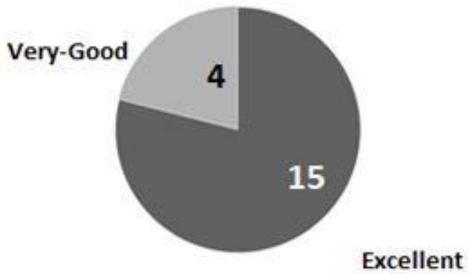

Figure 1. How was the overall experience of the off-class preparation, with the on-line material?

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?”, 52% of the participating students answered “As Expected”, 21% answered “Less Than Expected”, 15% answered “Much Less Than Expected” and 10% answered “More Than Expected”.

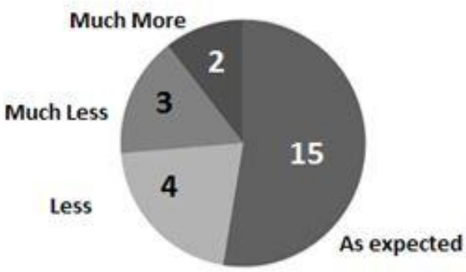

Figure 2. How long it took you to get prepared, with the on-line material in relation to the estimated duration?

4. IN-CLASS ACTIVITIES

Forty percent (40%) of the students, enrolled in the Machine Design Course, (25 people) participated in the in-class activities. Of those, 92% (23 people) participated in the preparation phase, watched and read the on-line material and replied to the quizzes and the evaluation questionnaire.

In-class activities began with a discussion, aimed at reviewing on-line material. Organized discussion activities and debates can be used to facilitate peer-to-peer knowledge exchange and a deeper engagement with the course content. Course concepts become more meaningful, diverse student assumptions are tested and perspectives explored. During the discussions or debates, students create teams with two or more members and, after each question, they are given the opportunity to discuss within their group and reach a joint answer announced by one of the members, as a representative of the group.

By a series of questions, posed by the instructor, students had the chance to retrieve and put forward the basic principles of friction, lubrication and lubricants.

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 while facilitating the development of team spirit. Indeed students by assuming a, more active than usual, attitude, soon felt more confident and relaxed and started to enjoy the process.

It was a good time for the following class activities, which were based on the concept of Active Learning. The advantages of Active Learning are indicated in numerous papers [19, 20, 21, 22]. We consider the excitement created by this methodology [23], as its greatest advantage. Between various approaches of Active learning, we have chosen to use Experiential Learning.

In Experiential Learning activities, students learn through immersive, hands-on learning experiences. The pedagogical benefits of these learning experiences have been well-documented in the literature and demonstrate the efficacy of simulation environments and modeling in enhancing learning [24]. Experiential learning activities can take a number of forms, including role-playing, experimentation demonstrations, labs, computer simulations, competitions etc. The intensification of the learning process was pursued by the creation of a collaborative learning environment in which the students played active roles, using knowledge, gained outside the classroom. A group of students dealt with the organization and implementation of a friction study experiment, while a second group was involved in an experiment involving the study of viscosity. With the use of simple materials from the school's machine shop, two simple experimental arrangements were quickly assembled.

A small amount of two lubricants, was used: a “thin” SAE 10 basic machine lubricant and a “thick” SAE 90 gear lubricant.

Students of the first group used a handmade ramp (Fig.3), with an attached protractor and a maximum tilt indicator, to experimentally demonstrate to the class the development of dry and wet friction of metals. The friction angle was measured in the case of the aluminum on aluminum contact. Then, a thin layer SAE 10 lubricant was applied to the aluminum surfaces and the friction angle was measured again. The experiment was conducted at room temperature (20°C). The whole process was repeated for the SAE 90 lubricant.

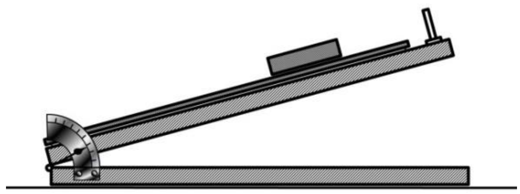

Figure 3. The friction angle measuring ramp

The second group of students used a handmade Engler viscometer (Fig.4), to present to the class the viscosity measurement of the two available lubricants (SAE 10 and SAE 90) at temperatures of 0 ° C, 20 ° C and 100 ° C. Glass bottles with containing the lubricants, were immersed in two baths, one with water and ice cubes and one with boiling water, in order to achieve temperatures of 0 ° C, and 100 °, whereas the temperature of 20 ° C degrees was the ambient temperature, at that time. The purpose of the activity was not to accurately measure viscosity, but to qualitatively understand the effect of temperature on a basic property of lubricants.

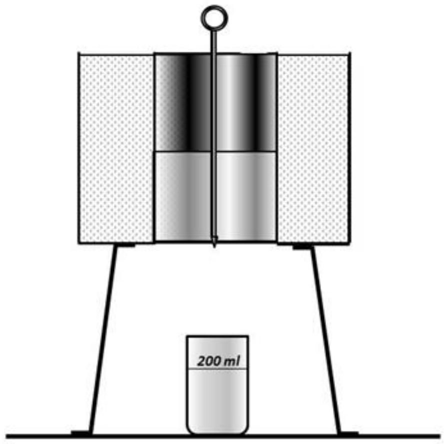

Figure 4. The Engler-type device

The results of the tests were used as a stepping stone for a consecutive discussion on the various applications of lubricants. Most students (more than 90%) were able to argue about the suitability of certain lubricants for use in specific applications, such as internal combustion engines, speed reducers, gas turbines, conveyors, building machines, cooling equipment etc.

During the last part of the course we dealt with the evaluation of in-class activities. During the discussion, students had the opportunity to express their views on Flipped Classroom, which in their vast majority were very positive. To the question: “How difficult did you find the in-class activities?” 72% of the participating students answered “Not at all”, 24% answered “Just a Bit” and 4% answered “A little”.

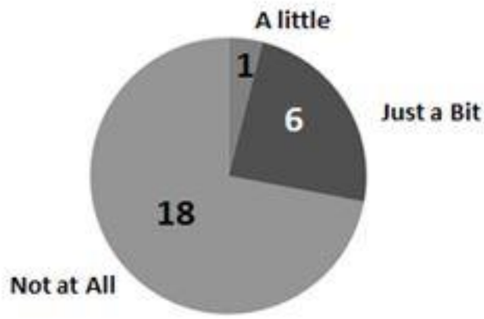

Figure 5. How difficult did you find the in-class activities?

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?” 76% of the participating students answered “A lot” and 24% answered “Very much”.

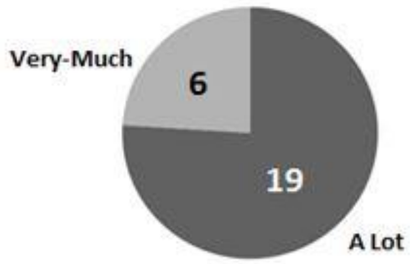

Figure 6. Do you think that in-class activities have helped you to improve the level of understanding of the lesson you achieved during off-class preparation?

5. CONCLUSION

During a two-hour class, a substantial part of the basic Tribology concepts, that are very important to the mechanical engineer, was dealt with. The achieved learning outcome turned out to be considerably large, in relation to the allocated teaching time. Although no control group was set up for a more direct quantitative comparison, an evaluation based on qualitative assessments on 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. Learning, despite the intensification of the lesson, due to limited time, was accompanied by a significant level of satisfaction that has, in general, been found to contribute to the formation of long-term memory and the consolidation of knowledge. In conclusion, teaching “Tribology and Lubrication Basics” turned to be a great opportunity to implement and access Flipped Classroom and Blended Learning. They were confirmed as flexible and powerful knowledge transfer tools with many possibilities for broader implementation.

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