A Project Based Learning Approach in Teaching Mechanism Kinematic Analysis

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Although a causal relationship, between the active involvement of students with the education process and the level of learning outcomes, has already been clearly demonstrated by numerous researchers, the choice of appropriate educational methods and "tools", for effectively engaging students in the learning process, remains a serious problem for every teacher. This study demonstrates the application of Project Based Learning - PBL method to the teaching of a Mechanism Kinematic Analysis course, in a higher education institution, and highlights the specific factors that have effectively contributed to the remarkable increase in student performance.

Keywords: project based learning, student involvement, excitement in learning, student interaction

INTRODUCTION

Having, within my academic responsibilities over the past years, a course in "Mechanisms and Machine Theory" at the School of Pedagogical & Technological Education (ASPETE), I faced the challenge of transmitting to my students a great amount of tricky theoretical knowledge during an academic semester while also aiming to give them the ability to develop useful skills and professional mentality. The study and design of the mechanisms include, on the one hand, their operational competence determined by the tracks and velocities of the members of the mechanism and, on the other, their safe operation by comparing the stresses developed in the members of the mechanism with the strength of the material. (Norton, 2003, Ghosh & Mallik, 2006) To find the stresses in a machine element, one has, at some point of the process, to formulate a system of equations of equilibrium. In case of a mechanism member, though, the rigid body equilibrium equations are transformed into D'Alembert equations taking into account its linear and angular acceleration as well as its mass and moment of inertia. (Ambekar, 2007) In order to determine the successive positions (tracks) of the members of a mechanism, and also the corresponding velocities and accelerations at each successive position, it is necessary to solve a series of equations systems at the two-dimensional or three-dimensional space, the design of which requires the determination of the mechanism's in polar coordinates and their conversion into cartesian-ones by using complex numbers' transformations. Solving such equation systems is a difficult task and requires special mathematical manipulation, since they contain both linear and non-linear equations. After presenting, for three years, the above mentioned learning material, using only the traditional way, I thought that a Project would be a great way to frame my lectures and help my students to consolidate knowledge. Therefor I began to plan the activity, based on the good old Kilpatrick's ideas (Kilpatrick 1918). Meanwhile, a more modern method: Project Based Learning, seemed more promising, and I

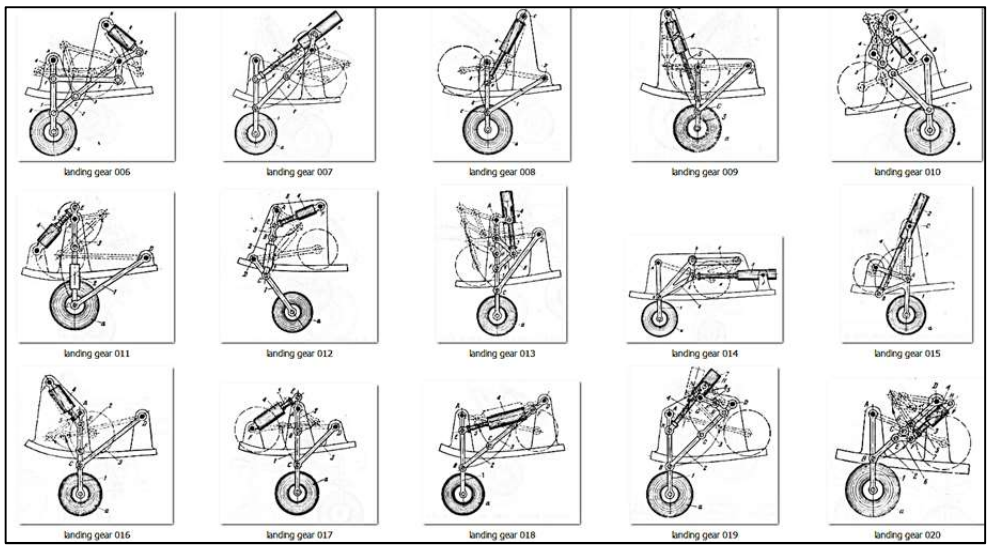
assumed that it was worth trying it out. Whereas Project Method aims at attracting the students' interest to the course content by involving them to specially designed, purposeful activities, Project Based Learning goes much further: In Project Based Learning, the project is not an auxiliary activity, but it becomes the essential tool for the dissemination of academic content while helping students to develop skills useful in their later professional life. Students work to resolve an important problem over a substantial period of time, thus becoming immersed in it, pursuing answers from various angles, working collaboratively, thinking critically and engaging in reflection and revision.

METHODOLOGY

According to (Markham et al., 2003), project-based learning is "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex authentic questions and carefully designed products and tasks". Nevertheless, according to (Barron & Darling-Hammond, 2008, Thomas, 2000), introducing a project into the learning procedure is not enough to qualify it as PBL, unless five definitive features are met: 1) a central project; 2) a constructivist focus on important knowledge and skills; 3) a driving activity in the form of a complex question, problem, or challenge; 4) a learner-driven investigation guided by the teacher; and 5) a real-world project that is authentic to the learner.

The projects had to be relevant to the course curriculum but they also had to be able to inspire students by putting them in the position of real practitioners, commissioned with something real and truly important. The basic idea was to select a central theme that would allow the formulation of different yet equivalent projects, to enable students to create, working in small groups, results both independent and comparable. Trying to move the "center of gravity" to the students, a number of mechanisms' categories, from a classic mechanisms handbook (Artobolefsky, 1975), were presented to them and a long discussion took place on their characteristics and applications. Although the decision on the general theme of the project was supposed to be made using formal "brainstorming", the, rather unanimous, result was reached by voice-vote! The general theme of the projects would be "Landing Systems". A number of images, showing twenty six different landing system types, were uploaded on-line. (See Figure 1).

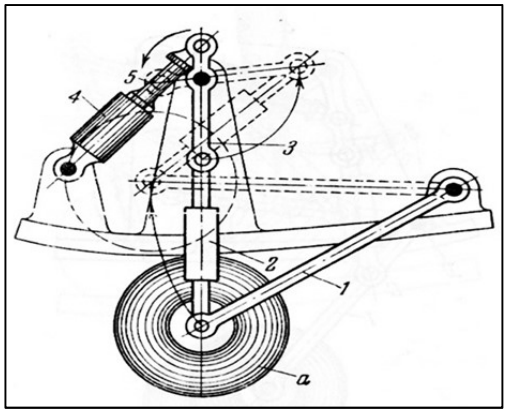
FIGURE 1
LANDING SYSTEM TYPES, UPLOADED ON-LINE



On each of them, the landing system is actuated by a hydraulic cylinder whose piston moves between two end-positions at a constant speed. The landing gear is shown at the two end-positions corresponding

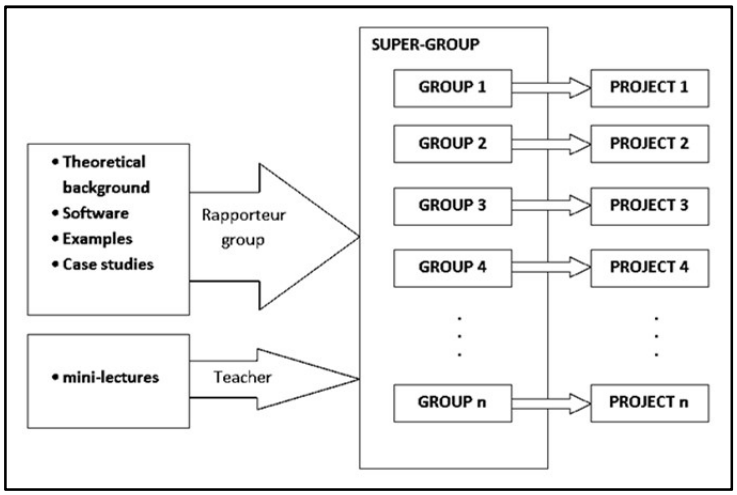
to the end-positions of the piston (full and dotted lines respectively). The mechanism parts' dimensions should be determined from the image after determining, the distance of the lower point of the fuselage to the ground, when the aircraft is landed. (See Figure 2)

FIGURE 2
LANDING GEAR (TYPE 011)



The task of the project was defined as follows: Students should study one of the given Landing Gear types. Students would form three- or four-member groups and designate the type of landing system, they wanted to study, to a student in charge of coordinating the distribution, based on a first-in-first-served criterion. The teaching time was reorganized to serve the project. The classical lectures were replaced by super-group sessions, during which, the students, under the guidance of the teacher, proceeded to decompose and gradually solve the problem. Theoretical material and relative examples were made available to students online and some of the groups were voluntarily tasked with suggesting methods of solving each stage of the problem. The rapporteur groups contacted the teacher in person and by mail to pose questions and receive guidance. Eight two-hour sessions followed by mini-lectures by the teacher aimed at filling in the theoretical gaps that occurred during the sessions. During the sessions, a number of questions emerged, which led to new assignments to groups of students to suggest a method for dealing with them. The groups were encouraged to combine methods known from their previous studies as well as original material from the Internet. Although each group had the task to study a particular mechanism, due to the common general theme, the problem approach was more or less common and allowed all students to function at a second level as a super-group.(See Figure 3).

FIGURE 3
GROUP STRUCTURE OF THE CLASS



Since the super-group was anyway in place to support the knowledge transfer, it was chosen not only to accept but to reinforce cooperation between the different groups rather than the competition and the pursuit of excellence. As a result, various type of interaction took place, justifying the term "super-group", instead of the term "class":

- Know-how exchange: Information, inquiry results, methods and software were circulated.
- Coaching: Members of more agile groups assumed roles of advisors, experts, reviewers and results evaluators helping their colleagues in other groups.
- Technical assistance: During the phase of the model construction market research results were shared on materials, shops, costs and often common procurements lowered the cost of the materials.

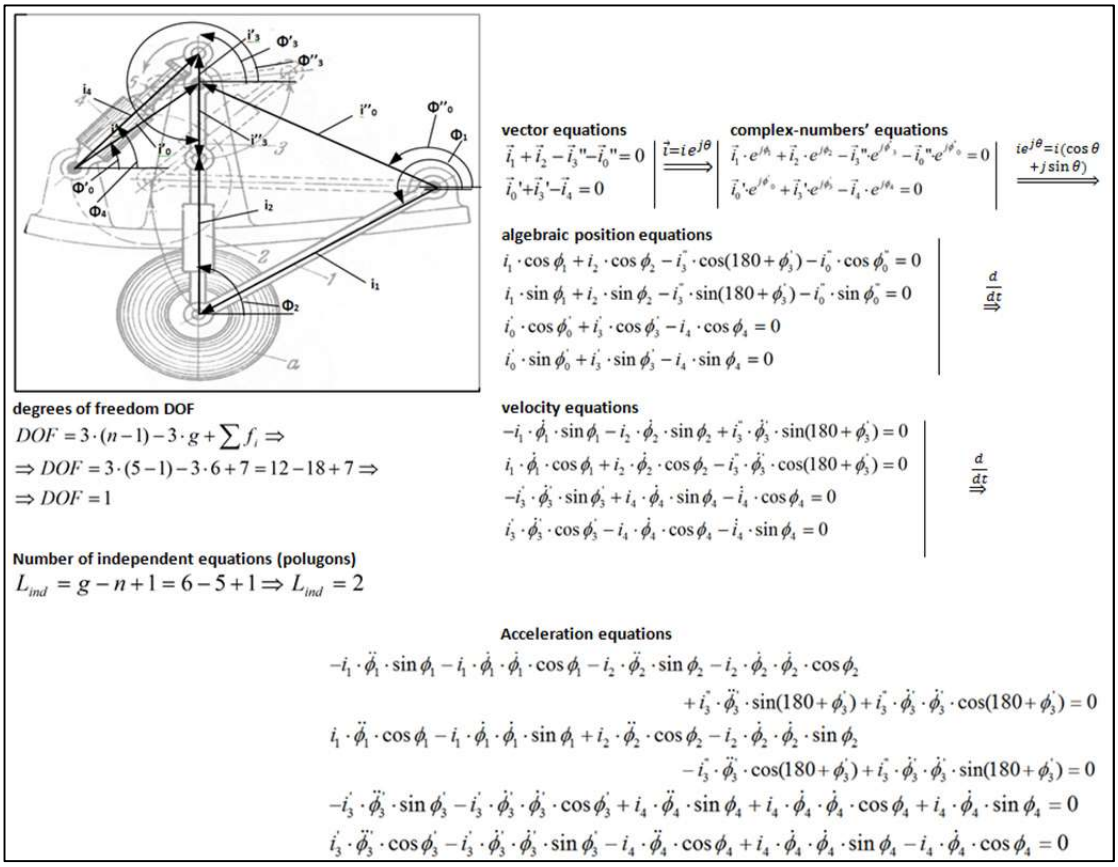
To ensure feasibility within the semester's time frame, the project was limited to the determination of the positions, speeds and accelerations of the landing system members for ten consecutive, equally spaced, positions of the piston. At first, each group had to verify that the chosen mechanism could be fully controlled only by controlling the position of the piston. The students had to formulate the independent vector equations that described the mechanism. The vector equations should be transformed into a system of algebraic equations and solved for the successive positions of the piston. The students had to derive also the equations describing the angular velocities and those describing the angular accelerations and solve them for the corresponding piston positions. The results i.e. the positions (θ, r) of the landing system members, as well as their velocities and accelerations corresponding to each of the ten piston positions should be graphically presented. All these should be included into a report. A working plywood model of the mechanism should be constructed. Both the report and the model would be presented during a daily workshop at the end of the semester.

RESULTS

Ninety eight (98) students, enrolled at the course, formed twenty six (26) groups, and nineteen (19) of them finished the project, produced the required deliverables and presented their work. Fourteen (14) of these groups (54%) acted as rapporteur in various cases presenting theoretical issues and/or methods. Twenty three (23) students (23%) of the students assumed, in various occasions, the role of a coach, or of an expert for students from other groups. In six (6) of the eleven (10) sessions (55%) a mini-lecture (average duration of 34 minutes) was given by the teacher and one (1) was given by a guest speaker from the Hellenic Aerospace Industry. In the rest of the sessions students preferred to collaborate and seek their

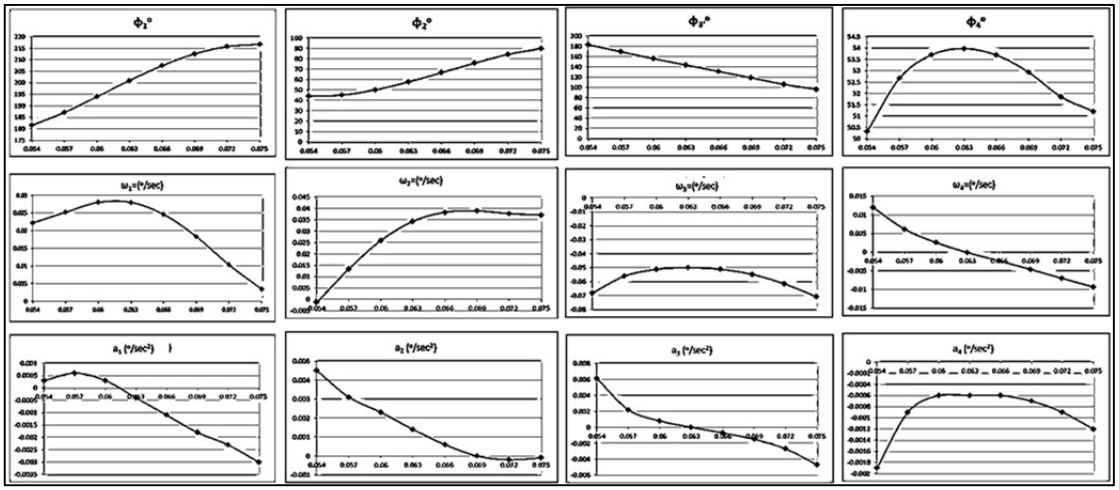
peers' advice. An example of the work of one of the groups, concerned with the mechanism shown in Fig. 2, is summarized below in Figure 4.

FIGURE 4
STUDY OF A LANDING GEAR MECHANISM



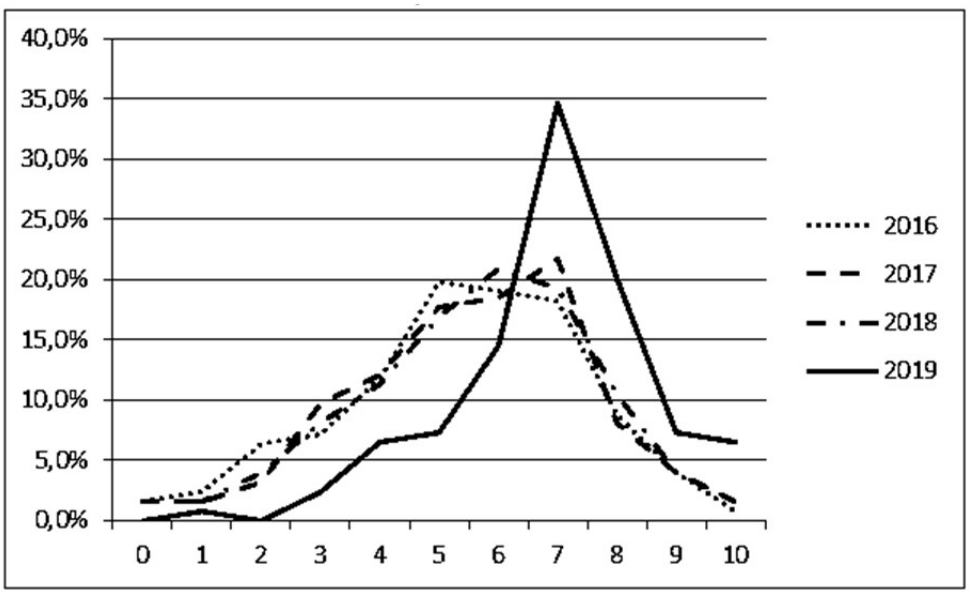
The problem of solving the above equation systems, and in particular the system of non-linear position equations, was overcome by using the Microsoft EXCEL's © Solver © ad-on. The results for the above mentioned example are shown in the diagrams of the Figure 5.

FIGURE 5
MECHANISM MEMBERS' POSITION, ANGULAR VELOCITY AND ANGULAR ACCELERATION



Since the academic content of the course did not change, and final exams remained the way of students' evaluation, a quantitative estimation of the PBL effect could be based on their final grades. By looking at the results shown in Figure 6, one can observe that students' performance, this last year, significantly improved in relation to the previous three years. There is a clear shift from 5,5 average grade, in years 2016-2018, to 6,9, in 2019 (+25%). The percentage of students with grade over 5 from increased from an average of 71% during 2016-2018 to 90% in 2019 (+26%). The more often occurring grade rose from 6 to 7 (+17%).

FIGURE 6
STUDENT'S PERFORMANCE INCREASE DUE TO THE IMPLEMENTATION OF PBL IN 2019



At the end of the course, the students reviewed the whole process by answering an on-line questionnaire. The results are summarized in Table 1.

TABLE 1
STUDENTS OPINIONS ON THE PBL COURSE

	Opinions % of total				
	most negative	negative	indiferent	positive	most positive
Was it difficult to go through the project	9	46	31	8	6
Was it interesting to go through the project	4	11	21	40	24
Total semester workload compared to the average of other courses.	17	39	23	13	8
Do you feel satisfied with the results of your group assignment	0	0	3	34	63
How you rate the knowledge you aquired from the mini lectures	0	5	7	67	21
How do you rate the knowledge you aquired on your own	0	4	8	54	34
How you rate the knowledge you aquired from your colueges	0	3	11	44	48
How do you rate the overall experiece	0	0	2	47	51

CONCLUSIONS

During an academic semester a substantial part of a Mechanisms and Machine Theory course was dealt with, using Project Based Learning. The achieved learning outcome turned out to be substantial and student performance clearly increased compared to previous years, while class characteristics, such as participation and interest presented an impressive improvement. The most interesting findings, however, did not come from the students' performance but from the program implementation process itself. Learning, despite the intensification of the lesson, due to increased workload, was accompanied by a significant level of satisfaction. The enthusiasm generated by the subject's choice, which gave students the opportunity to do something so realistic and exciting, pushed them to a higher level, dominated by quest and creativity, while multidimensional interaction with their peers transformed their solitary pursuit of knowledge into a social endeavour. The encouragement of a collaborative culture, instead of a competitive confrontation and the pursuit of excellence, contributed to the emergence, validation and sharing of individual ideas and achievements. The general conclusion is that there a lot to gain from PBL and many more could be learnt from its implementation.

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