

COMPUTER AIDED ENGINEERING AS A PROBLEM BASED LEARNING COURSE

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Abstract

This paper presents the Course M-99-201 Computer Aided Engineering from the master program Manufacturing Engineering, where Problem Based Learning (PBL) is used as an active learning method. During the course students learn different commercial CAE software packages. These tools are first presented to the apprentices as self learning tutorials, which they have to accomplish in order to be able of using them for the problem solving process. The assignments are presented in an order that students may use the learned tools for solving the problems posted. For example, at the beginning of the course the software WorkingModel2D™ is used. A typical problem at this beginning is the design of a transmission of a washing machine as the 2D simulation software is suited for the required analysis and decisions. After the second course week the students start with the tutorials of ADAMSVIEW™, which is a 3D Multibody Simulation package. During the second month students have to analyze an automotive windshield wiper and a suspension for improving its performance parameters. Several examples of solutions given by the students are presented with the aim to illustrate the type of problems as also the solutions approaches.

At the end the results of a blind survey posted to the students is presented. Here the perceptions of the students regarding their learning experience and their attitude and feelings about the active learning process vs. the traditional methods are analyzed.

Keywords: Problem Based Learning, Computer Aided Engineering, Multibody Systems

1. Introduction

The expected final result of an engineering program is not only the acquisition of technical knowledge and skills of the students, but also the enhancement of their communications skills, creative and critical thinking and ethical behavior. The ability of creative thinking and innovation skills is being enforced in the last years because of the increased competition in the global market. (Tornkvist, 1998); (Basadur, et al., 1990)

This paper presents a case study from the master program Manufacturing Engineering at the course M99-201 Computer Aided Engineering. Problem Based Learning (PBL) is here used as an active learning method. The benefits of PBL are that it provides the scenario that motivates and engages the students in the problems and, at the same time, faces them with real professional life situations (Schmidt, 1995). The paper continues the research started since 1998 regarding the use of active learning methods at the master program Manufacturing Engineering at ITESM, Monterrey Campus, (Leon, 1998) following the educational model established at ITESM (Martín, 2002)

The didactic method mainly consists in confronting the students with engineering problems derived from our own professional practice, which the learners have to analyze for defining a process of resolution and achieving an acceptable elucidation. A special web communication tool, the *Blackboard Academic Suite*TM is used, which is based on commercial browsers and facilitates placing the information of the course and the problems' descriptions to the apprentices (Figure 1).

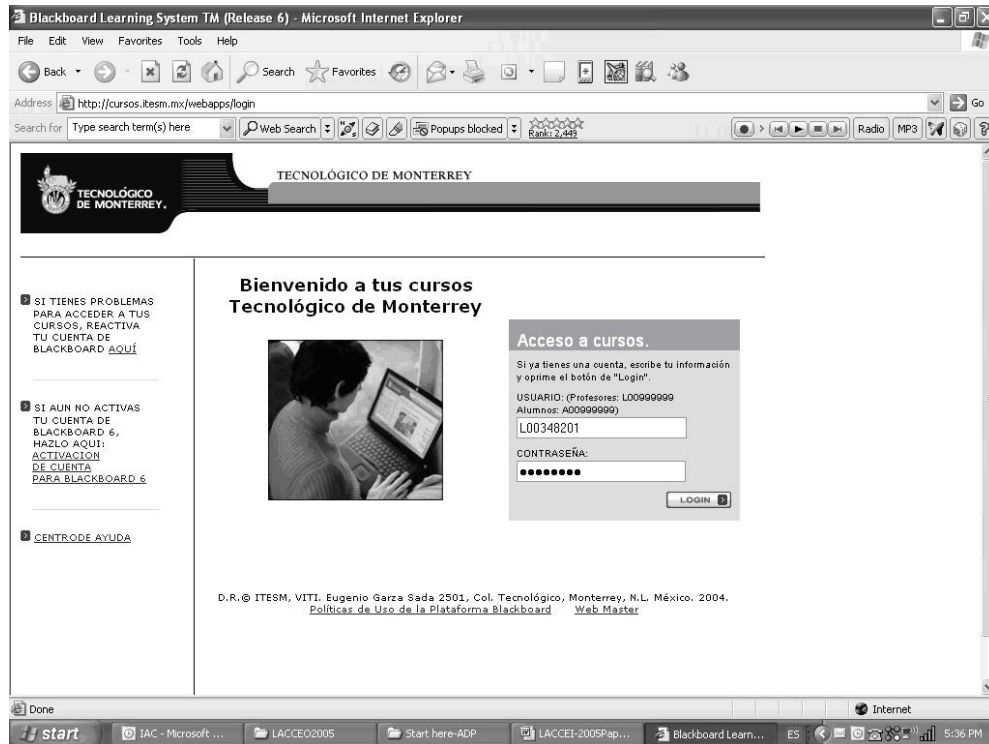


Figure 1: Entry interface of the web communication tool Blackboard Academic SuiteTM

The students get access to the course through the web communication tool after they register. As the structure of the courses on this web tool is unified for the ITESM system, students are familiar with it. Examples of solutions given by the students to the problems assigned to them are presented with the aim to illustrate the type of problems as also the solutions given.

2. Course Content and Information

The content of the course M-99-201 Computer Aided Engineering is described in the web communication tool as is shown in Figure 2. The web tool facilitates also the communication between students and instructors.

A welcome greeting and an abstract of the course in English and Spanish gives students the first information of the course (Table 1).

The students learn different commercial CAE software packages as are also used in industrial enterprises. These tools are first presented to them as self learning tutorials, which they have to accomplish in order to be able of using them for the problem solving process. Through these tutorials the students learn the user interface of computer software for engineering analysis. Afterwards they learn to solve typical engineering design problems using these tools. .

The first part of the course is focused on 2D and 3D multibody systems. WorkingModel2D and ADAMS are used to analyze the cinematic and dynamic behavior of commonly used mechanisms, as for example the oscillating device of washing machines, automotive suspensions and camshafts.



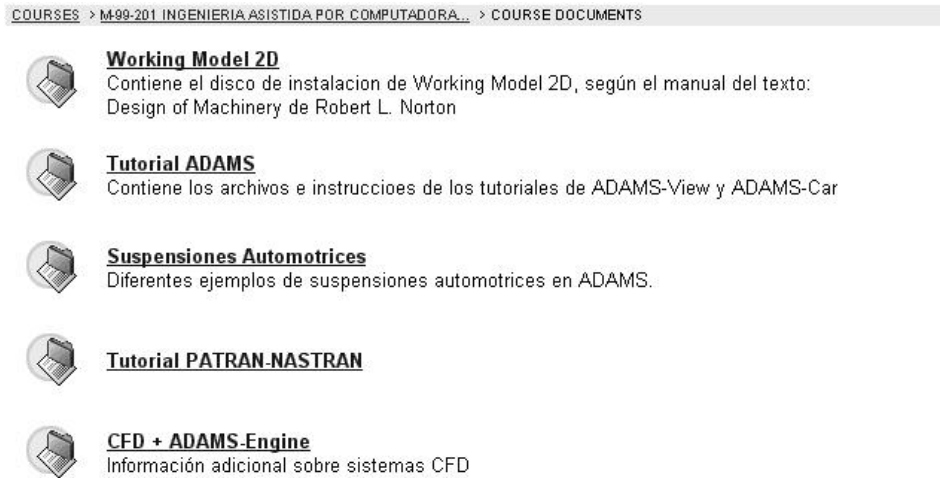
Figure 2: Course Content and Information

Table 1: Welcome greeting as it appear in Blackboard Academic Suit

<p style="text-align: center;">Welcome to the course M-99-201 Computer Aided Engineering</p> <p>The course is conceived as Problem Based Learning (PBL). In this course you will learn to solve engineering problems using computer tools as WorkingModel2D, ADAMS, MSCPatran and MSCNastran, which are used in leading companies of the world.</p> <p>Many forefront Universities are applying this method in the education of CAE.</p> <p>We want that this course will become for you a truly creative and enriching experience. The objective is that you not only learn the user interface of the software packages. The actually important thing is that you learn the theoretical foundations that sustain the cinematic and dynamic behavior and analysis as well as the stresses and deformations occurring in machines using multibody systems and finite elements methods and applying them to mechanical systems. You will as well acquire abilities in ways and methods of solving engineering problems derived from the product design and development process.</p> <p>This way we hope that you will feel the emotion of the creativity, when developing truly innovating solutions, so that you will see the possibility that your results can be applied to real problems. This hardly can happen if the problems given to you are extracted from a book.</p> <p>For that reason we have selected engineering problems of diverse areas, in which we have had participation in real projects. These problems have been adapted for this course, so that they allow you to have one more realistic vision of the problems that you will have to face in your professional practice.</p>
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The use of a web tool also facilitates the students the access to the required course documents as tutorial instructions, tutorial files, as shown in figure 3.

Figure 3: Course Documents section with tutorials information



3. Module 1: Problems of Plane Mechanisms

The problems are presented to the students in such an order that they may use the learned tools for solving them. At some stages the students have to go to the laboratory and use computer software. For example, in this case, at the beginning of the course the software WorkingModel2D™ is used. The students have to accomplish during the first 2 weeks 6 tutorial exercises at the computer lab as contained in the Working Model 2D tutorial. In Figures 4 and 5 are shown examples of the exercises contained in the referred tutorials.

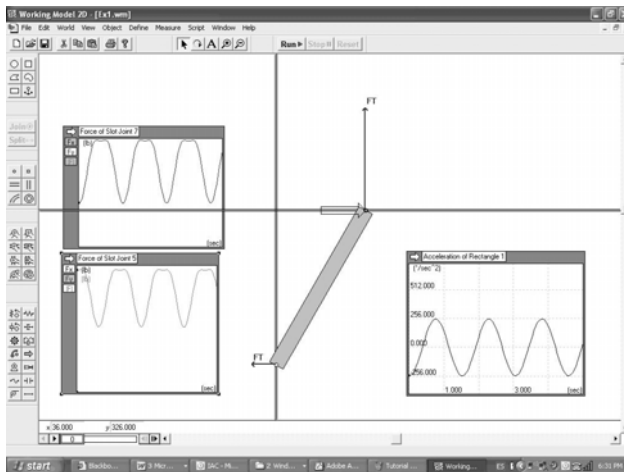


Figure 4: Exercise 1 Working Model 2D

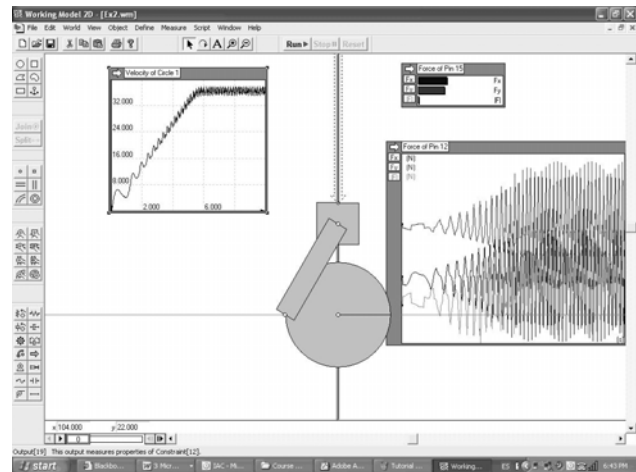


Figure 5: Exercise 3 Working Model 2D

In Figure 6 is shown how the tutorials and problems for the first month are presented to the students. During this first month students are asked to solve problems based on plane mechanisms



Fig. 6: Assignments for the first module 2D mechanisms

The students have to deliver the solved exercises of the tutorials at the “drop box” of the web tool.

The first problem for starting the problem solving atmosphere is the design of a folding chair as the 2D simulation software is suited for the required analysis and decisions.

The students are encouraged to improve the functionality of a folding chair for making it more competitive at the market. First a discussion takes place in the classroom where the students are asked to reveal what they already know of existing solutions for folding chairs. They are asked to draw from scratch a sketch of a commercial folding chair as are well known from parties, meetings, etc. and to deliver their sketches to the professor. At this moment, commonly only few students truly remember how folding chairs work. This way they are motivated to learn more about folding chairs and the right atmosphere for a creative learning is created (Entwistle, 1987)

The learners are then confronted with the Grueblers' Equations of plane mechanisms for calculating the degrees of freedom. Homework is assigned asking for researching existing commercial folding chairs as the way to understand the plane mechanisms on which they are based and how these mechanisms fulfill Grueblers' Equations. (Norton, 1999)

By the second course week, after students have fulfilled the required tutorial exercises, they are asked to develop a competitive folding chair and simulating its functions in WorkingModel2D. Following minimal requirements are stated to be fulfilled by the folding chairs:

1. Automatically folding when lifted

2. It is allowed to use a spring for the automatic folding.
3. If a spring is used, its parameters should be calculated.
4. The chair should not fold when the sitting person stands up
5. Folded chairs should allow to be stapled in minimal space for maximizing the number of chairs that may be transported in a truck.

3.1. Washing Machine Mechanism

After getting started in the problem solving environment with the folding chair assignment, the students are asked to build 2 persons' teams to solve a washing machine mechanism problem. This problem was subject of a project at our Center with a local enterprise. The objective of that project was to reduce the cost of the washing machines for remaining competitive against foreign competitors. The content of the assignment is described in Table 2. In Figure 7 is shown a solution proposed by one students' team.

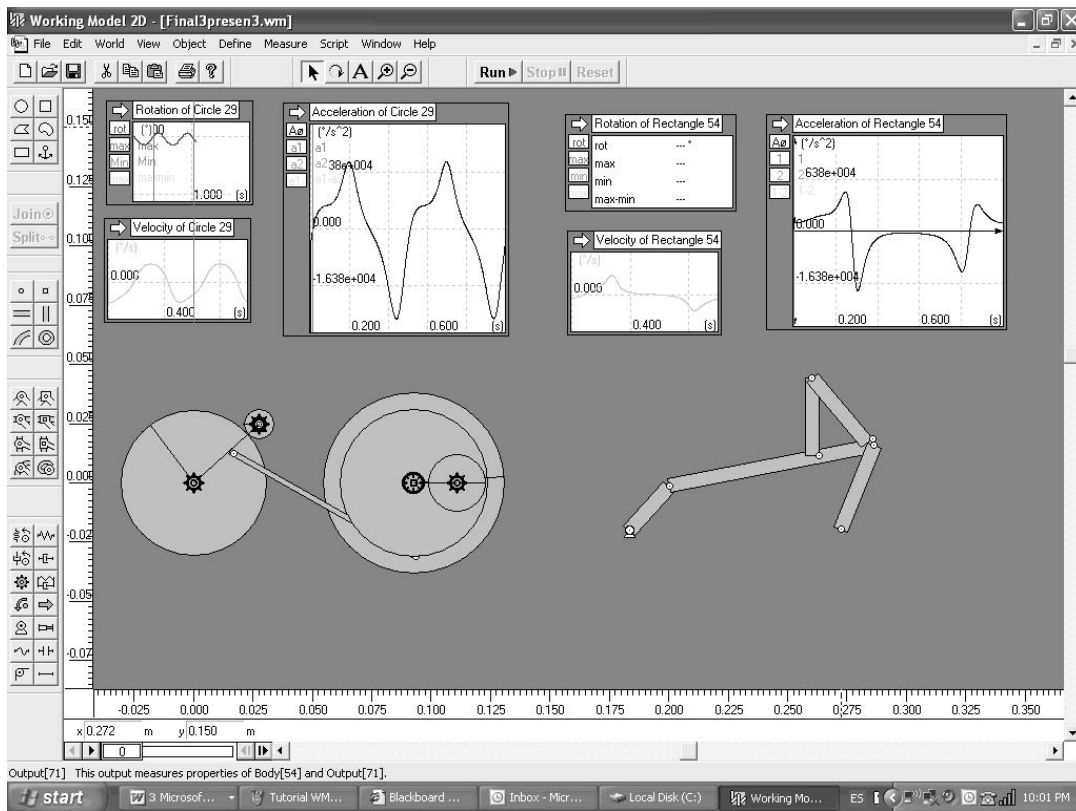


Figure 7: Solution attempt with a simplified mechanism

The solutions proposed are delivered at the drop box of the web tool. In this case the solutions are presented as WorkingModel2D files accompanied with a PowerPoint presentation that describes the solution process and results achieved. Only the instructor has access to the solutions posted in the drop box. During the following class each team has 10 minutes to present their solution and to argue their reasons. This is a first presentation and is not intended for assessment. A discussion takes place after each presentation, where all the students participate in commenting the pros and cons of each presented solution approach. The professor acts in this case as facilitator of the discussion.

Commonly the solutions achieved at this stage contain evident weakness and flaws, but the discussions during the presentations serve as guide for its improvement.

Table 2: Assignment Washing Machine Mechanism

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Problem 2

A local company that produces washing machines, (See Figure 1) is aimed at reducing its production costs. A preliminary analysis shows that the complex mechanism that makes the conversion of the rotation of the electrical motor to an oscillating movement for the agitator (Figure 2) presents high costs when compared with other foreign washing machines, which have more efficient mechanisms with smaller dimensions. It has been detected that the present oscillating mechanism (fig 3 a) and b) was designed many years ago and it contains parts with higher cost.



Figure 1

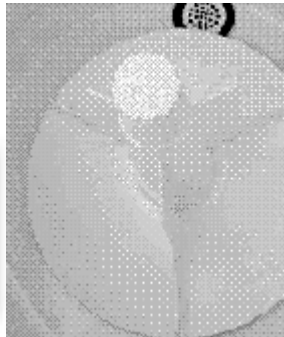


Figure 2

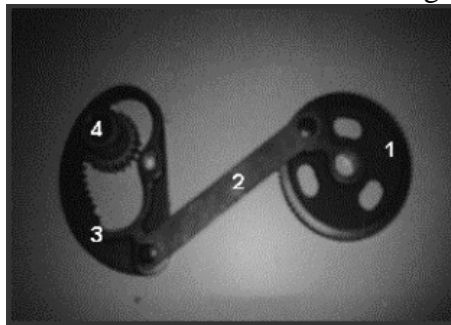


Figure 3 a)

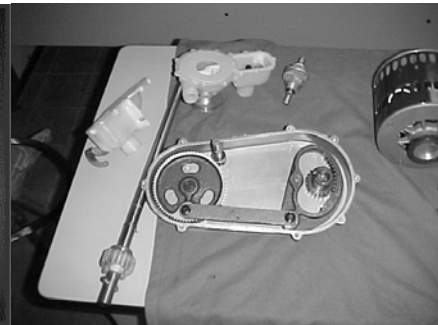


Figure 3 b)

View of the box with a combined crank-rocker mechanism combined with gears

Your team has been ordered to propose solutions for reducing the costs of the present mechanism. It has been stated that the angular displacement, the velocity and the acceleration profiles should remain as close as possible to the present ones, as the washing efficiency of the actual machine is satisfactory.

The project team has CAE software available, such as VisualNastran4D and ADAMS that allows making simulations and analyses for sustaining the proposed solution.

More information is available in: Design and Simulation of a transmission of compact washing machine of type oscillation, Master Thesis, Jose Antonio Canto Esquivel, ITESM. December, 2000, TT997 C3 2000.

The teams take note of the hints and tips given during the discussions and continue working on the improvement of their analysis and solutions. At this stage the students truly start realizing the importance of the CAE tools for solving this kind of engineering problems as it become obvious that without these tools the problem solving process would require more expensive and time consuming physical prototypes and experiments.

At the end of the month the assignments of the module are presented for assessment. The assessment process and rules are described in chapter 5.

4. Module 2: 3D Multibody Systems

After the second course week the students start with the tutorials of ADAMSVIEW™, which is a 3D Multibody Simulation package. This tutorial is more difficult and time consuming, as it is a professional software package with very sophisticated analysis capabilities. Students are asked to fulfill 12 exercises of the tutorial in 3 weeks. An instructor offers support at the Computer Lab for clarifying questions. In Figure 8 and 9 are shown examples of the exercises that the students have to solve in the ADAMSVIEW tutorials

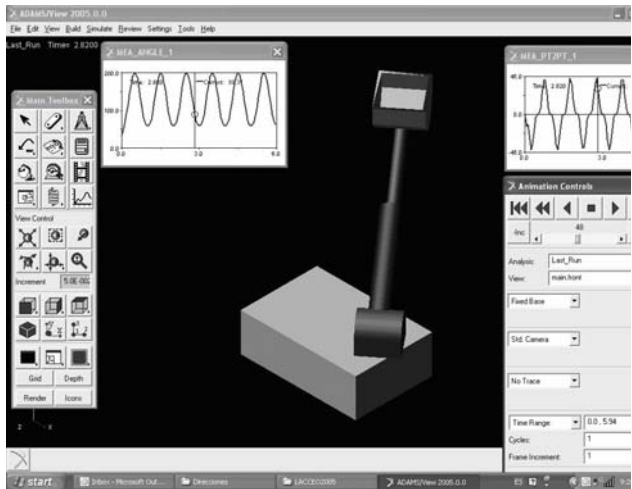


Figure 8: Exercise 7 ADAMSVIEW

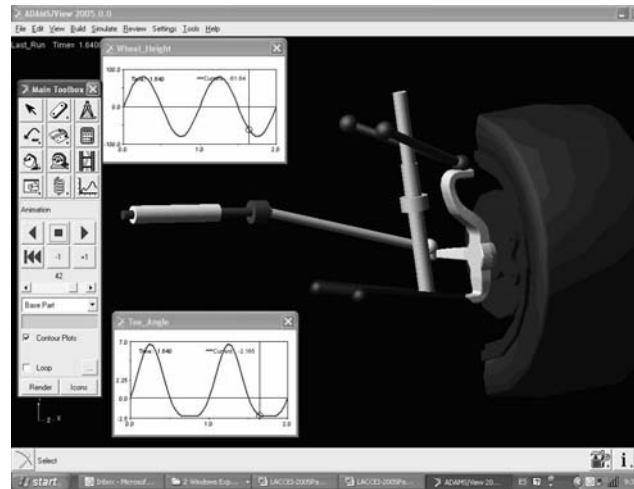


Figure 9: Exercise 10 ADAMSVIEW

Before starting with problems requiring 3D multibody systems packages for their solution, the transition from plane to spatial mechanisms from the point of view of the Gruebbler s' Equations is discussed with the students.

The interesting question of the degrees of freedom equations in 2D and 3D space is presented to them asking for an explanation (See Table 3). After the students realize the concept of superfluous constraints in spatial mechanisms, they are invited to develop spherical and truly spatial four bar mechanisms and to practice with ADAMSVIEW in free modeling 3D mechanisms as they did with 2D mechanisms in Working Model 2D.

For the next problem a case study is used that is useful for illustrating the transition from 2D to 3D mechanism problems. This is the case of a spatial windshield wiper mechanism (See Table 4) which also may be solved in a simplified way as plane mechanism with 2D CAE tools, but which require 3D CAE tools for a thorough solution.

First the simplification of the spatial mechanism as a mechanism is developed, as the students have not yet at this moment enough skills with ADAMSVIEW for modeling the spatial mechanism. In Figure 10 is shown an example of an analysis of the windshield cleaning mechanism with WorkingModel2D.

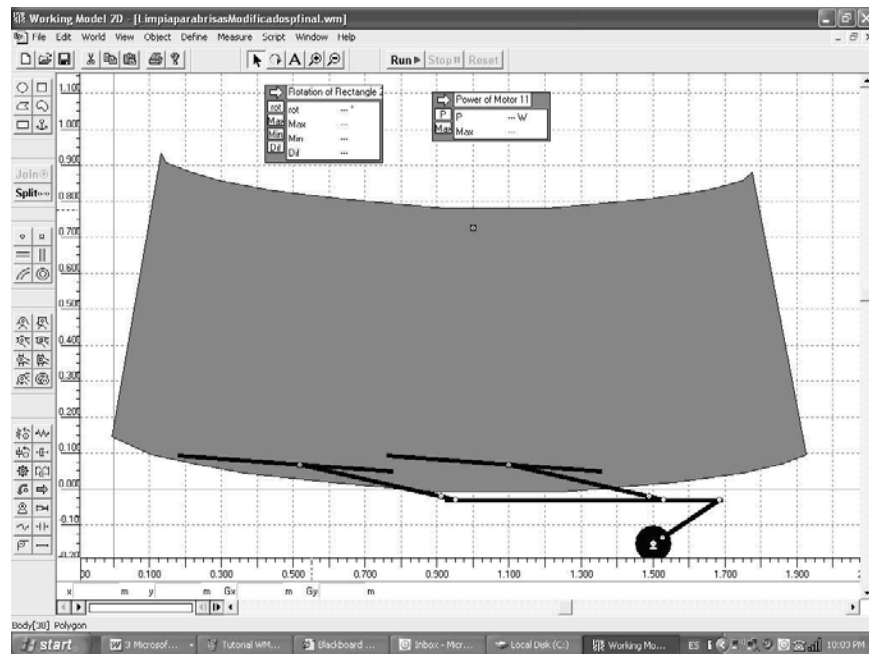


Figure 10: Windshield Cleaning Device Simplified as 2D Mechanism

In Figure 11 is shown the simulation of a windshield cleaning device as spatial mechanism, considering also the curved windshield surface and the blade holding mechanisms.

This example is also very well suited for asking the students to reflect about the differences in information content of the simulation models and the physical models.

For example the fact that the aerodynamic forces acting on the windshield mechanism during the movement of the vehicle at higher velocities are not present in this model is brought to their attention.

Also they are asked to analyze how much more accuracy of the simulation model could be achieved if the rubber blades of the mechanism are simulated as flexible bodies that adapt to the curve surface of the windshield.

As the solution of the windshield mechanism problem using 3D simulation software is a much more time consuming task than the 2D simulation, they are asked to evaluate how much more accuracy they won through the 3D simulation and if the conclusions achievable with the 2D package could have been sufficient for the problem to be solved.

Table 3: Gruebler Equations for four bars planar and spatial mechanisms

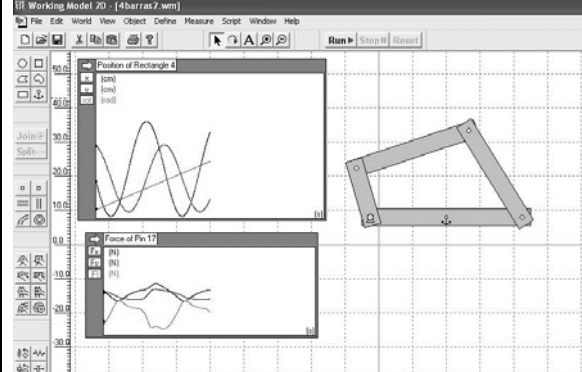
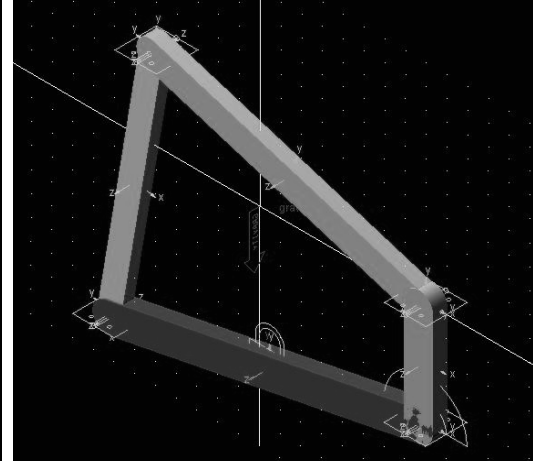

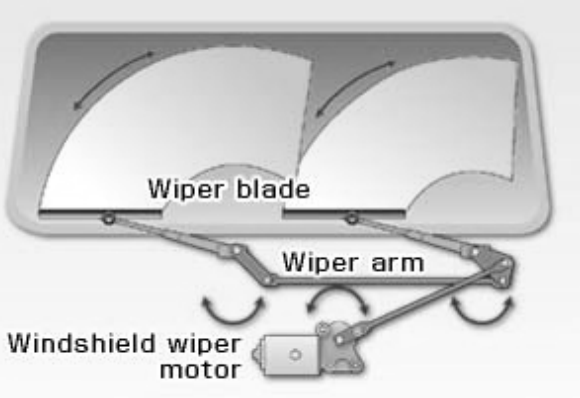
<p>PLANAR $DOF_p = 3*N - 2*J_2 - J_1 - 3$ $J_2 = 4$ $J_1 = 0$ $N = 4$ $DOF_p = 3*4 - 2*4 - 3 = 1$</p>	
<p>SPATIAL $DOF_p = 6*N - 5*J_5 - J_4 - 6$ $J_5 = 4$ $J_4 = 0$ $N = 4$ $DOF_p = 6*4 - 5*4 - 6 = -2 (!?)$</p>	

Table 4: Windshield Cleaning Mechanism

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Problem 3
 You have been ordered to make a modification to a light truck chassis of 5,5 ton for producing a microbus.

The chassis is provided with cabin, but this cabin is not well suited for the microbus function that it is desired to achieve.

The client of the project wishes to use as much as possible the frontal part of the cabin to reduce costs. However it is required to change the windshield by one bigger.

This decision requires the problem of the windshield cleaning mechanism to be solved, for the new dimensions, which will be approx 30 % wider and 20 % higher than the present one. Also the inclination of the windshield is going to be greater with respect to the horizontal. The present angle is of approx 55 degrees and the new one will be approximately 75 degrees.

Your project team is asked to make the pertinent simulations and analyses, for selecting the dimensions of the new mechanism. It is requested to verify by means of a simulation that the mechanism works properly before making the modifications and investing in the new components that will be required.

For reducing costs, the company wishes to use as much as possible the components of the present mechanism; avoiding to reject components. It should be considered, for example, to modify those that are required, whenever the modification cost is less than the acquisition of a new one.

In order to facilitate the task it is possible to use initially a simplified model, reducing the space mechanism to a plane mechanism, whose characteristics can be analyzed with a 2D simulation package. Nevertheless, to be sure that the mechanism works, it will be required that the final simulation will be performed as a 3D mechanism before building the prototype. You should identify following issues:

1. Which components of the mechanism are possible to be reused.
2. Identify the surface of the new windshield that is covered by the new mechanism.
3. Identify if the loads that act on the motor for the new mechanism can be assimilated by the existing motor?

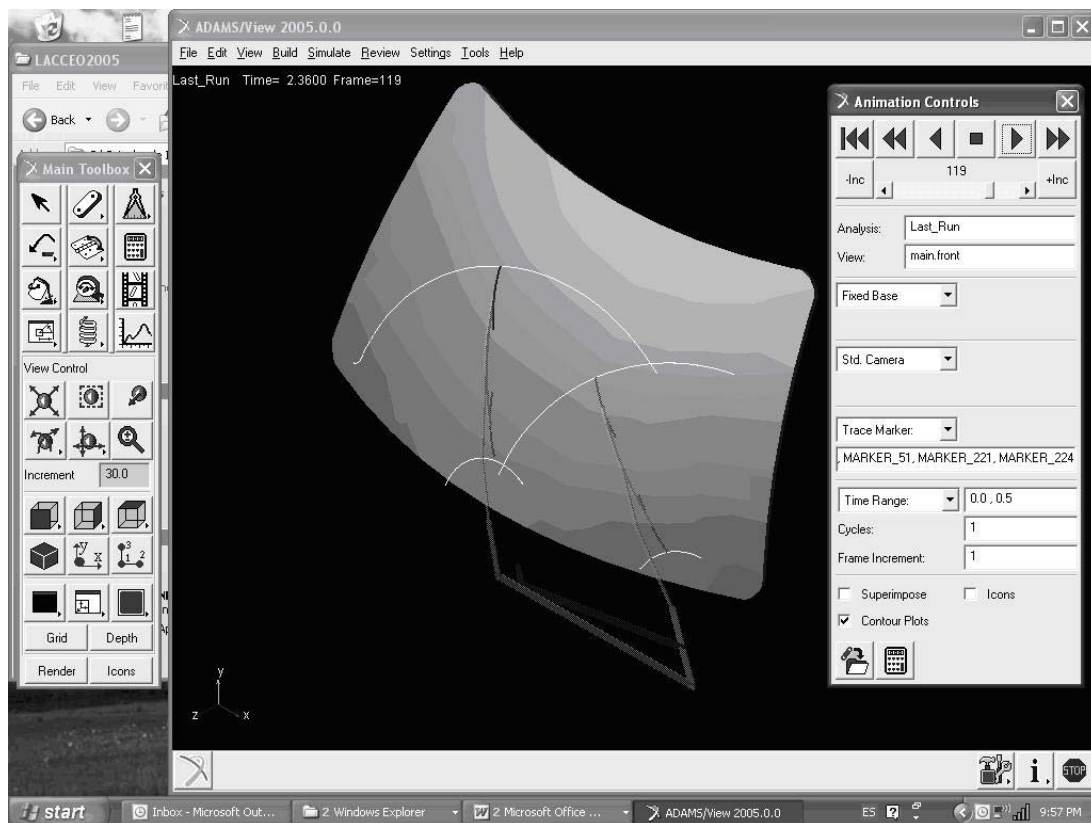


Figure 11: Windshield Cleaning Device as 3D Spatial Mechanism

These questions help them to identify that simulation models are representation of the physical models, which accuracy and usefulness should be kept in a relationship that makes sense from the engineering point of view in dependence of the problem to be solved. The economical impact of the solution is put on the foreground. Following guideline is giving for their decision taking process regarding the completeness and usefulness of the simulation model: as complete as required and as simple as possible.

5. The assessment process

It is a challenge for the professors to assess the students' performance and learning in these kind of active learning courses with real life problems, which do not have a single solution.(Mason and Bramble, 1997); (Wynder and Conway, 2001)

For making this process more complete a self evaluation and co-evaluation method was implemented. The assessment of the problem solving results was distributed: 50 % by the students and 50 % by the instructors.

For the monthly presentation of solutions the students get a guideline and form for self and co-evaluation. Each student is assigned with a fixed amount of points, which he has to distribute among the student teams during the assesment based on the guidelines for the evaluation. For example for the first monthly evaluation of the problem solutions the maximum amount of points that a team could get was 18. As it were also 18 students, the maximal number of point that a student could assign was calculated based on $18 \cdot 18 \cdot 0.88 = 286$.

This way the students were confronted with the challenge of assigning the points on a more analytical basis. The professor preserves a veto right with 50 % of the assessment.

6. Students' Survey

The results of a blind survey posted to the students are presented. Here the perceptions of the students regarding their learning experience and their attitude and feelings about the active learning process are analyzed. Also the experiences by handling the active learning processes during the whole semester are presented.

The survey posted is shown in table 5. The mean values of the answers given are shown for each question. The answers to questions 1, 2, 3, 6, and 8 show a clear preference for the PBL method. It is interesting that question 7, regarding how much more organized they feel when solving problems in a PBL course, was the only question at which the traditional course method was better evaluated. The questions 4 and 5 regarding how much more difficult they felt the solution process and how much easier they become aware of their learning and of their errors were evaluated almost even for both types of course methods.

Although the students had to work much harder, they show a clear preference for the PBL method. However several areas of opportunity are present, which require a further detailed analysis for identifying if the preference for the traditional method is inherently or if improving the implementation of the PBL course could influence in gaining more acceptance. The observation of the students' achievements during the problem solving process and their behavior during the presentations of their solutions, stimulate us for continuing improving this teaching method. One of the most important findings of this research is that students develop their own way of reasoning while analyzing problems in contrast with students of a traditional class.

TABLE 5: SURVEY RESULTS

Please answer to the following questions.
 PBL = Problem Based Learning

Write your evaluation from 1 to 7 for the class with PBL and for the traditional class

1. I agree completely; . I do not agree

	PBL Course	Traditional course
1. I am more motivated when I learn in a class where we solve real problems of the professional life and not typical problems of the text book.	1.59	3.35
2. I am more entertained when in class I can participate solving a problem in team with my companions	1.94	3.00
3. It pleases me more a class in which I can participate (going to the blackboard, to solve a problem, giving a presentation or explanation) than a class where I must be seated, listening to what the professor says and taking notes.	1.82	2.71
4. I feel better when I solve a problem that is very difficult, whether I alone or with my classmates without the professor has given the answer or has helped us completely.	2.18	2.29
5. In a PBL class it is easier becoming aware of my errors and how much I am learning, as well as how much the other classmates learn than in a traditional class in which I become aware of how much I learned until the day when I get the results of my examination.	2.59	3.28
6. I realize better of what I am able to do when I must solve a problem in a PBL class, that listening to the professor.	1.82	2.59
7. I have become more organized in learning when solving problems in a PBL course	3.12	2.88
8. I realize what a creative person I am when I achieve the solution of problems.	1.88	2.41
9. What is what you have liked more of the course?	learning software use variety of solutions real problems creativity impulse	2 9 2 9 1
10. What is what you dislike of the class?	Just a short time software education ambiguity of answers insufficient computer equipment work load evaluation	6 5 2 1 2 1

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