

## **AC 2007-1020: 3-PHASE MULTI SUBJECT PROJECT BASED LEARNING AS A DIDACTICAL METHOD IN AUTOMOTIVE ENGINEERING STUDIES**

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### **3-Phase Multi Subject Project Based Learning as a Didactical Method in Automotive Engineering Studies**

#### **Abstract**

Modern life requires a faster transfer of information and shorter education courses while at the same time supposing a higher quality of specialized and soft skills from young academics. Companies expect young engineers not only to be able to apply theoretical knowledge in practice, use the appropriate tools, work autonomously, but also to be able to work in teams, and to present engineering results clearly and impressively.

For the past nine years, we have been applying Project Based Learning (PBL) in three distinct phases as a didactical method within the degree course's curriculum in the department of Automotive Engineering. The main task is to motivate the students to apply theoretical knowledge in practice as soon as possible. The young engineers not only deepen their specialized knowledge but they also develop real systems and design industrial products.

The first phase of this multi subject PBL begins in the first academic year and encompasses the second and third semesters. A set of project topics is defined, based on the subject "Information Systems and Programming", with an emphasis on ANSI C and numerical methods of calculation. To solve the tasks the students usually need information from subjects such as mathematics, mechanics, fluid mechanics, machine dynamics, measurement engineering, electrics, electronics, and strength of materials. The entire project – from task description to project presentation – is done in English, which is not the students' native language. The students work in teams of three or four. Generally, more than two groups develop the required software solution to generate a competitive environment. At the end of the semester we rank the projects and nominate a winning team.

The second phase of the multi subject PBL starts in the sixth semester. The tasks either come directly from the automotive industry or are modeled on real-life engineering problems, which the students have to solve using professional tools.

The third phase is carried out in the seventh semester during an internship in companies in the automotive segment. The main focus is set on practical training and the direct application of both the special and soft skills in the professional world.

This paper concentrates on the description of the first phase of the multi subject PBL and reports on our excellent experiences using this method. As early as their second academic year, we can show that our students are able to develop new innovative methods of calculation and software programs that have been internationally recognized.

## Introduction

The main aim of degree programs at the Universities of Applied Sciences (UAS) in Austria is to help students acquire professional and scientific qualifications both on a theoretical and a practical level<sup>1</sup>. In the department of Automotive Engineering and Railway Engineering at the UAS Joanneum in Graz, we offer a 4-year undergraduate degree. It is very important to apply modern didactical methods in the degree program as early as possible to increase the efficiency of knowledge transfer and to fortify the students' motivation to learn and to co-operate actively. Our task is twofold: on the one hand we have to convey theoretical basics in mathematics, strength of materials, thermodynamics and heat transfer, machine elements, electrical, electronic and measurement engineering, whilst on the other hand, we must encourage our students to apply this knowledge in projects and engineering tasks directly. Additionally, companies expect young engineers to be able to present the results of their work persuasively. Because of the very high mobility and internationalization in the automotive industry nowadays, it is very important for the graduates to be able to communicate in at least one foreign language, which is usually English.

For these reasons we decided to develop a 3-phase multi subject didactical method, based on the well known methodology of project based learning (PBL), see Figure 1.

The main idea is to define engineering tasks according to the level of education and to equip the students with the necessary information and skills to solve them. This includes education in special technical subjects, processing of electronic data and writing of documentation and reports, project work and project management, preparing of power point presentations and practice in English.

During the first phase – in the second and third semester of the degree program – we mainly concentrate on the theoretical and language education. We do not require or expect that the project results could be applied as industrial products directly or that we could publish them. But occasionally our students come up with outstanding programs<sup>2</sup> which merit further application or dissemination. This phase will be described in detail later.

After a short break of one semester for exam consolidation, excursions to companies, etc., we start with the second phase of PBL. While the final results of project work should be summarized and presented in the sixth semester, the project work itself often started in the fifth semester. To accomplish the tasks in the designated period of time, the students need specific technical knowledge and excellent organizational skills. Our showcase project in the automotive engineering program is Formula-Student. This international competition is initiated by the Society of Automotive Engineers and allows our undergraduates not only to design and build a race car, but also to compare their knowledge and skills with that of their peers worldwide<sup>3</sup>.

The third and last phase is inherently linked with the seventh semester of the degree program and comprises of an internship in the automotive or railway industry. The students typically do this practical training in OEMs or supplier companies and are responsible for finding their own placements. Here they get the chance to prove their skills and knowledge in the professional world.

## 4-year (8-semester) Undergraduate Degree Program and the 3-Phase Multi Subject PBL

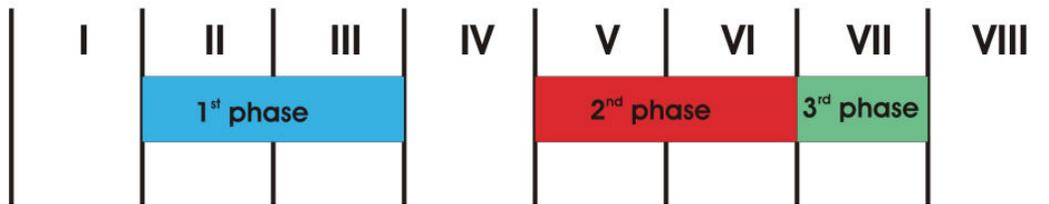


Figure 1: 4-year (8-semester) Undergraduate Degree Program and the 3-Phase Multi Subject PBL

### Structure of the First Phase of 3-phase multi subject PBL

The first phase of the 3-phase multi subject PBL didactical method is carried out in the second and third semester of studies at the Department of Automotive Engineering and Railway Engineering, Figure 1. The main curriculum subject for the projects is "Information Systems and Programming". The students learn MS Visual Basic<sup>®</sup> (VB) in the second semester and ANSI C in the third. The final results of the projects are always stand alone software programs that can be installed from a CD. The CD includes the setup files and the user manual. The software should be a complete and tested product.

In the second semester we decided to teach VB because this is a programming tool that allows the students to design a Graphic User Interface (GUI) quickly and easily. Additionally, they learn how to use it to extend the functionality of MS Office<sup>®</sup> programs like MS Word<sup>®</sup>, MS Excel<sup>®</sup> and MS Access<sup>®</sup> (which were already taught in the first semester). The students have to develop a user-friendly GUI that allows input and output of data as text, 2-D and 3-D graphics, files and sounds. They are generally allowed to use other tools, too, but the main and required software tool is VB. The tasks in the second semester mostly correlate with modern automotive engineering topics. The aim is, on the one hand, to demonstrate to the students the current direction of engineering development; whilst on the other hand, stimulating their motivation and basic interest in the automotive sector. The project work is carried out in German (our native language).

"Information Systems and Programming" in the third semester concentrates on ANSI C and the development of a DLL (dynamic link library). The functions of this DLL should be called from a VB GUI, should process the digital data and finally should pass it back to the VB main program that could output it in different ways (text, charts, graphs, pictures, sounds, movies, etc.).

We decided to teach ANSI C because this is a typical engineering programming language which is used not only for the development of DLLs but also in Embedded Systems and it is also the basic language for MATLAB<sup>®</sup>/Simulink<sup>®</sup> - one of the most important tools for calculation, simulation and data processing in the technical world of automotive and aviation engineering. As a structured programming language ANSI C is very suitable for numerical mathematical methods. The task of each project in the third semester always includes the implementation of one numerical method at least<sup>4</sup>. Additionally, to solve the given task, the students have to apply

their knowledge of other subjects taught in the same semester. This is a real challenge because it requires not only the elements of project management but also of knowledge management.

In an effort to broaden the interdisciplinary nature of these undergraduate projects, English is introduced as the project language in the third semester. In addition to general language development, the course General English 2 (which runs concurrently to the project) focuses on topics and skills which the students will need in order to complete their projects successfully. These include:

- E-mail writing to facilitate communication with team members, supervisors and if necessary, external advisors or subject experts
- Minute taking to help record the decisions made and milestones discussed
- Technical writing: specifically how to structure short technical reports, write user manuals and abstracts
- Giving short, informative and persuasive presentations and developing techniques to deal with questions and answers

In the second semester and third semesters alike, the students are required to select the project task from a predefined list of project proposals. In general, two or more groups of three or four members work simultaneously and competitively on the same task. On occasion, because of restrictions of hardware components or special instructions from industry partners, we approve only one group. By having the option to select their own project, the students have the chance to delve into subjects of particular interest to them, but which are not taught in such depth and detail in regular lectures. To support the students with the essential information they then require, we offer additional meetings and lectures accordingly. Each team is supervised by two or more tutors. The Information Systems and the English lecturers always supervise the teams. Additionally, subject experts (lecturers in the department or external professionals) can be responsible for special mentoring.

The main parts of the first phase of PBL are:

- Definition of project tasks
- Kick-off meeting
- Project work
- Project presentation
- Evaluation of the projects

#### *Definition of the tasks*

The tasks are defined and projects supervised by the lecturers/supervisors in the department of Automotive Engineering and Railway Engineering. The process of definition goes through a number of stages. Initial ideas for projects are circulated to identify possible overlaps or areas where different subject specific tasks may complement each other. If the scope of the project is deemed feasible for the timeframe of one semester, lecturers/supervisors then draw up a more detailed task description. Experience in other institutions has shown that for project based learning to be successful, it is essential for all task descriptions or assignments to conform to a

standard template<sup>1</sup>, thus the task descriptions adhere to a particular format in which the requirements, in terms of programming tools, deadlines, etc. are laid out clearly. While the minimum requirements are defined, in general no limits are placed on the students' creativity nor on the amount of time they should invest in order to complete the projects. New tasks are developed for each year group, although there have been follow-on projects in some exceptional cases.

### *Kick-off meeting*

Students are first introduced to the projects at a kick-off meeting with the supervisors early in the semester where the supervisors present the tasks they are responsible for. In addition, they receive detailed information on the scope of the projects, the deliverables<sup>5</sup>, the timetable and deadlines and the evaluation criteria. A one page task description of each project is then displayed and time allotted for project groups to form and make their selections. In order to foster a certain element of competition, two or more groups can select a particular task. This kick-off meeting generates an unexpected degree of negotiation within the group as they vie for projects which interest them most. The process of claiming 'ownership' of a task as opposed to having it prescribed contributes greatly to the success of the projects in our experience.

### *Project work*

After initial consultation with the supervisors and the assignment of duties within the team, students embark on the main part of the project work. They will typically go through the following stages (though not necessarily always in the order given):

- Researching topics
- Finding technical/mathematical solutions
- Acquiring relevant background knowledge and skills
- Designing and programming software
- Documenting the process from research to development and finally to output
- Reflecting on project management, team work and the performance of individual team members in the form of a brief written appraisal
- Handing in software and documentation on a pre-defined date

The role of the lecturers, as subject experts, is to guide the students through these stages and give them the tools necessary for finding the missing pieces of, what for them is often a great puzzle, at least in the early stages.

### *Project presentation*

For the final step, each team is required to give a presentation approximately one week after handing in the software program and the project documentation. The presentation is given in plenum to the other students from the year group and the subject supervisors. Presentations are given in the style of a technical sales pitch. The students should show what their 'product' can do and convince their audience that their solution is technically superior to other 'competing' products. Question and answer sessions following the presentations also give

the students the opportunity to discuss their approaches and methods in some detail. This oral communication of the steps taken and solutions reached is an essential part of the overall task. These presentations also form part of the overall evaluation process (to be discussed below in more detail). Students and supervisors alike evaluate the software programs based on information given in the presentations and predefined criteria. Specifically they look at the design and functionality; innovation in terms of technical solutions and user-friendliness are also taken into account. The presentations themselves are evaluated in terms of language content and delivery skills.

### *Evaluation of the projects*

The evaluation of the project work is undertaken in two steps: first continuously during the project and then after the hand-in of the software and the project documentation. The software program is tested independently by the subject expert and the Information Systems lecturers. The factors used for appraisal are the fulfillment of the task, user friendly handling, GUI, programming techniques, feasibility of calculation and visualization, stability and the reliability of the software. The documentation is also assessed by the special subject tutor and the English lecturer.

The final evaluation consolidates the assessments of the software, documentation and the technical sales presentation. Additionally, these evaluations form part of the final marks in each subject related to the project work. This motivates the students to fulfill the requirements in all project parts.

### **Some Example Projects**

The following two examples of a second and a third semester project represent typical tasks for teams of three students. Further examples of such projects are presented in another paper<sup>4</sup>.

#### Example for a second semester project: “Rear View”

Rear view cameras allow drivers to safely view objects behind the vehicle through CCD cameras. Due to the fact that wide view angle cameras are in use, the images produced by those systems are distorted and would therefore lead to false estimations of distances by the drivers. In order to compensate distortions geometric transforms have to be employed to modify the location of pixel values within the spatially distorted image. The students’ task was to implement such a spatial transformation for equalizing the rear view.

The students decided to tackle this problem by employing a rectangular calibration grid. The distortion of the grid viewed by the rear view camera was then used to evaluate the coefficients  $a_{11}$ ,  $a_{12}$ ,  $a_{21}$ ,  $a_{22}$ ,  $t_x$ , and  $t_y$  of the matrix  $A$ , governing the affine transformation from the distorted image to the equalized one

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & t_x \\ a_{21} & a_{22} & t_y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \quad (1)$$

or shorter  $\vec{x}' = A\vec{x}$ . Affine transformations are generalizations of Euclidian transformations. Under affine transforms, lines transform to lines but circles become ellipses. Length and angle are not preserved.

The coefficients of the transformation were determined by taking three linearly independent points in a region of the distorted picture and assigning them to the related points on the rectangular grid. The linear system resulting from this procedure has then to be inverted. The result of such equalization is presented in Figure 2.



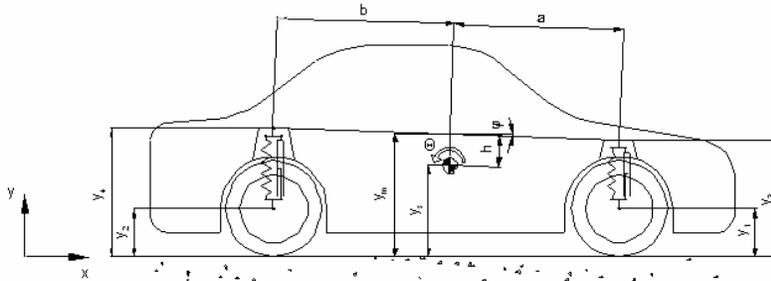
**Figure 2: Picture of a student taken with the rear view camera (left) and the same picture equalized by the presented algorithm (right)**

In this project the students' attention was directed towards affine and projective geometry, linear systems, and data visualization.

Example for a third semester project: "Sleeping Policemen"

In order to make car drivers reduce speed in the vicinity of schools, hospitals, old people's homes and similar locations, roads are often furnished with cumbers known as sleeping policemen. These, however, sometimes can cause damage to cars as the underbody of the car strikes the ground, in some cases even though the prescribed speed limit has not been exceeded. It would therefore be interesting to be able to predict the motion of the body of the car, when driving with a given speed over the sleeping policemen of a given geometry.

To simplify matters the car was represented by a single track vehicle model consisting of a rigid car body with two sets of massless spring-damper systems attached to it and representing the front and the rear wheel suspensions (see Figure 3). For user-specific characteristics of the car and the road profile, the motion of the car body was numerically simulated and conveniently visualized.



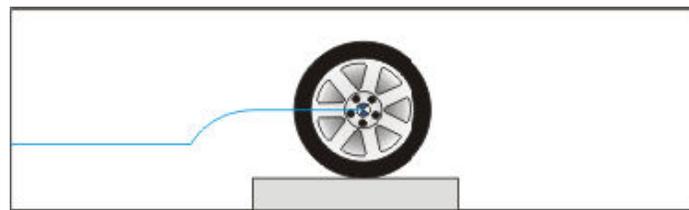
**Figure 3: Schematic representation of the two-wheeled model used for the simulation of the vehicle**

Lagrange's equations were used to transfer the mechanical model into a mathematical model. In order to solve the two generalized coordinates  $y_m$  and  $\varphi_m$  (the height of the center of mass above the ground and the pitch angle, respectively), it was necessary to solve a system of two coupled second order differential equations

$$\begin{aligned} \ddot{y}_m(t) &= f_1(t, y_m(t), \dot{y}_m(t), \varphi(t), \dot{\varphi}(t)) \\ \ddot{\varphi}(t) &= f_2(t, y_m(t), \dot{y}_m(t), \varphi(t), \dot{\varphi}(t)) \end{aligned} \quad (2)$$

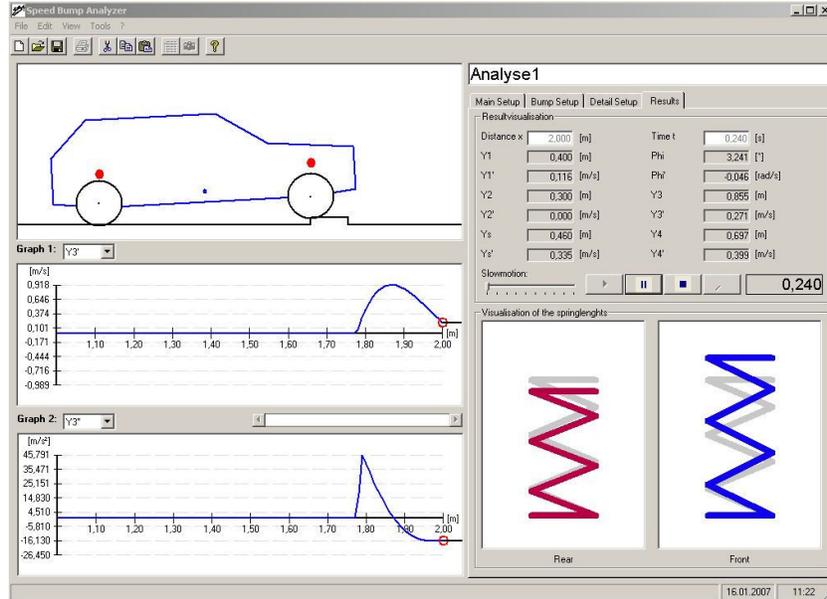
Due to non-linearity, the differential equations had to be solved numerically. For this purpose the 4th order Runge-Kutta algorithm was employed.

The students also properly simulated a wheel-to-bump contact by taking into account the wheel and speed bump geometries (see Figure 4).



**Figure 4: The simulation of the wheel motion by taking into account the geometry of the speed bump**

In Figure 5 we can see the GUI of the program, with a representation of the car (a sports utility vehicle was chosen in the illustrated application), the velocity and the vertical acceleration of the suspension of the front wheel as well as the rear and front spring compression or expansion. All graphs mentioned above can be displayed as a movie in order to demonstrate time-dependency.



**Figure 5: Graphical user interface of the program designed by the project group. The graphs show the velocity and the vertical acceleration of the suspension of the front wheel. Rear and front spring compression or expansion is represented in the lower right hand windows.**

In this project, the students' attention was directed towards vehicle dynamics, analytical mechanics, the numerical solution of a coupled system of ordinary differential equations, and the animation of dynamical systems. They benefited from supplementary lectures in mechanics and engineering mathematics.

## Conclusions

As a didactical method Project Based Learning (PBL) helps to apply 'real' world oriented - learning and on this note has value beyond the demonstrated competence of the learner. It encourages the students to use higher order thinking skills and learning concepts as well as basic facts. The project work in this first phase is very important because it provides for in-depth understanding. Simultaneously, the students learn to be responsible for and to have ownership of their learning within the curriculum. PBL allows for a variety of learning styles and utilizes various modes of communication. That means that the students are encouraged to be innovative and to work in a team. Learning cuts across curricular areas, i.e. it is multidisciplinary in nature. Projects promote meaningful application of knowledge and skills, connecting newly acquired information with students' past performances. The project tasks in the first phase of the 3-phase multi subject PBL are like a 'play ground' and the students can experiment with different methods, project management styles and assess their work by themselves. The teacher is a facilitator of learning, a supervisor and mentor.

The learning process is valued as well as the learning project. The assessment is congruent with instruction, i.e. performance-based. Because the evaluation is done not only by the supervisors but also by the students, the latter are motivated to be very fair and precise in their application of the assessment criteria.

The old-school model of passively learning facts and reciting them out of context is no longer sufficient to prepare students to survive in today's automotive industry.

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