Research Projects as a Part of a
3-Phase Multi Subject Project Based Learning
in Vehicle Engineering Studies

Abstract

At the previous ASEE World Congress we presented an overview of our 3-phase multi subject didactical method as an integrative part of our degree program Vehicle Engineering\textsuperscript{1,2}. Our work has shown that the first part of the 3-phase method helps sophomores learn to work autonomously, but also to be able to work in teams, and to present engineering results clearly and impressively.

The second phase of the multi subject PBL starts in the third academic year and encompasses the fifth and sixth semesters. A set of project topics is defined, based on different specialized technical subjects, with an emphasis on the development of real products. One of the most important projects is the design, assembly and testing of a real racing car. To cope with the project tasks, the students have to manage complex duties starting with the technical objectives through to marketing the final product. Sometimes they enter academic competitions to prove and to measure the quality of their work.

The main challenge of supervising juniors in this second phase of our Multi Subject Project Based Learning is that while the students are highly motivated to work on real-life engineering problems, they are often only partially able to cope with all the problems that arise because of lack of professional experience or knowledge.

This paper concentrates on the description of the second phase of the multi subject PBL and reports about our excellent projects. Each year a new student team autonomously designs, assembles and tests a real racing car in less then 150 days. The students prepare the budget, develop a marketing concept and enter the SAE Formula Student contest. They were winners over all in 2006 and set a European record in acceleration in 2007. Furthermore, the students have developed, in cooperation with their supervisors, special measures to ensure knowledge transfer between two or three team generations.

Introduction

The 3-Phase Multi Subject Project Based Learning\textsuperscript{4} is a special didactical method that aims to help preparing the students for their later professional life by successive, constructive project work. In each phase we firstly assist the young engineers to identify their personal abilities in solving problems at some technical level and then we coach them to develop specific new skills. In the first phase the students work in small groups, competitive to each other. With the first phase\textsuperscript{1,2} we aim

- to encourage the students to use higher order thinking skills and to learn concepts as well as basic facts;
- to help the students to apply theoretical knowledge in practice in a very early stage of their education;
- to train them to work in teams;
- to encourage the students to be responsible for and to have ownership of their learning within the curriculum;
- to encourage the students to develop methods to connect new learning to students’ past performances;

In the second phase the students also work in a team but not competitive to each other. We offer two variants of research projects: internal – the tasks are defined in the Department of Vehicle Technology – and external – the problem definition is a part of an industrial project. The project settings are much challenging, complex, elaborating, and the students have to apply technical and project management knowledge as well. The second phase of MS-PBL starts in the junior year of study and takes generally up to 9 months.

The most important internal research project in our department is "Formula-Student", initiated by SAE®. The students have been participating in the competition since 2002 and the project became an integrative part of our education structure. Nowadays, Formula-S is the biggest student project at the University.

The student team has up to 40 members from 4 different departments – Vehicle Technology (ca. 30 students), Industrial Design, Management International Processes, and Information Design. This project starts in summer before the junior year of study and takes 12 months. In the last two years the students decided to enter the main contest in Detroit; for these teams the project takes 22 months.

The main task is to design and manufacture a racing car, due to the Formula-S requirements, and to compete with up to 120 university teams worldwide. Our undergraduates have the possibility to compare their knowledge and skills with that of their peers worldwide. To cope with this very complex task the students have to define a clear team-structure and to design a project concept and project schedule. They are also responsible for the complete design, manufacturing, experiments and tests, fund raising and budget, marketing, presentation and documentation. The Formula-S contests take place at different race courses worldwide. Our FS-team enters the European contests (Great Brittan, Germany and Italy) as well as the main contest in Detroit, USA. The students have to organize the transport of the car and all necessary utilities, and the transfer of the team members, their accommodation, catering, registration, participation to the meetings, etc.

The main challenge is the transfer of knowledge and experience. Each year a new team of juniors is composed. This means that the only persons who continuously are involved in the FS-project are the faculty advisor and the supervising experts, Figure 1. To be successful in the very short time for planning, engineering, manufacturing, testing and preparing for the contest, the students must develop special knowledge transfer methods.
From the kick-off meeting to the winner's rostrum

In the second phase of MS-PBL the students have to use not only a broad spectrum of technical knowledge and engineering tools, they are also able to apply the trained capabilities and experiences collected in the first phase of MS-PBL\textsuperscript{1,2}.

The SAE Formula-Student project is the biggest and most important students' project during the whole course of study in the Department of Vehicle Technology. This project is performed in the junior year of study simultaneously with the regular courses. The participation in the project is not obligatory for the students, but every year 25-30 students are strongly motivated to manufacture an own racing car and to compete with it against international rivals. Furthermore, no students in each new team have been members in the old one. The consequence is that supervisors and students have to develop special methods for optimum knowledge transfer; all milestones and deadlines have to be reached in order to achieve highest performance.

In contrast to the first phase, there is only one and very large project team – more than 40 students are involved. The students and the sub-groups within the team are not in a competitive relation – quite the contrary, they have to be perfectly coordinated in a well balanced team. The aim is to win an international academic contest.

![Team-Structure](image.png)

Figure 1: Team-Structure. Each sub-group has its own leader.
The project work starts with a kick-off meeting. The students define the sub-groups; nominate
the leaders of the groups and the project leader, Figure 1. They define the most important
milestones, deadlines and responsibilities.

The knowledge transfer from the previous team to the new one starts before the kick-off meeting.
Some of the new-team-students attend the competitions with their colleagues and collect
impressions and experiences, build networks, etc. Several workshops of two or even three
Formula-S generations are carried out before and after the kick-off meeting to ensure continuity.
Very important for the efficient knowledge transfer is the development of a correct, complete,
well-structured, and comprehensible documentation. In the first phase of MS-PBL the students
learned a lot about design of technical documentation. The challenge in this project is the
combination of diversity and complexity, on the one side, and the use of English, as a non-native
language, on the other side. All reports, presentations, the complete correspondence and the
information exchange have to be done in English.

The project management is very complex because the students have to develop, manufacture and
present a real racing vehicle. They set up the project time schedule together with the faculty
supervisors but the project leader is responsible for its fulfillment. The sub-group workflow
coordination is essential for the success of the project. Shape-design and technical calculation,
component purchasing and negotiations with sponsors, meetings and tests must be done in the
scheduled order and if necessary to adapt it.

The car shape is designed in cooperation with students of the Department of Industrial Design at
our UAS, Figure 2. The material, the colors, and the varnish are harmonized with the
requirements of the young design engineers. The sketch idea is realized later in a 3-D CAD- tool
(CATIA V5).

To describe the structure and the content of the project work of the different team groups in
detail would exceed the maximum length of this paper several times; therefore we have chosen
to explain the performance mechanism on the basis of two examples: one mechanical and one
telemetric. Even though, the main focus of education in our department is set on the mechanical
systems, construction, calculation and simulation, the students are asked to handle electronic and
electrical problems related to the development of the racing car.
Based on the engine developing experiences of the previous racing car the students received the task to find new engine concepts and to adapt the peripherals. Firstly, the engine group had to compare available engine concepts, suction and charging systems; then the students had to design new systems or adapt the existing one according to the valid competition rules. The main emphasis was on saving weight and ensuring safety. Figure 3 and Figure 4 show the design of two variants of the air intercooler and its packaging. The students used CATIA V5 and completed the task during the design tutorial. The supervisor helped to evaluate the results but the selection and final implementation of the proper system was made by the students themselves.

Figure 3: Double tube air intercooler and packaging of the assembly

Figure 4: Single tube air intercooler and packaging of the assembly

Another task was to develop a telemetric system to collect measurement data from the chassis. The students had to select the sensors, and to design the data collecting system. They acquired several physical signals from the chassis suspension, driving and coupled axles. The young engineers designed the electrical circuits, Figure 5.
Figure 5: Electrical circuit for steer position measurement

Figure 6 shows the self designed and assembled layout of the measurement unit. The students designed additionally a CPU-unit to collect and save the data autonomously.

Figure 6: Self designed and produced layout of the measurement unit

The place choice for the sensors was a great challenge because in some cases the sensors did not fit into the destined gap, or it was impossible to wrap them, Figure 7. An additional confinement was the very restricted budget because it was not always possible to buy the optimum sensor. The young developers were forced to change the concept and to make compromises. In some applications they found out that the parameters of the sensors did not fulfill the system requirements because the requirements changed during the development, respectively they did not take some characteristics into account in advance. The development and the application of a measurement system was a special challenge for the prospective automotive engineers. They worked extremely hard and with a remarkable enthusiasm.
The students decided to place the complete system on the back of the car but they used it only during the adjustment tests, Figure 8.

To perform the tasks the students need some infrastructure. Most of the systems are available in the Department of Vehicle Technology. The students are allowed to use the workshop infrastructure as well as some of the test beds but they are always supervised by experts from the department staff, Figure 9.
The students are allowed to use the workshop infrastructure as well as some of the test beds. During the project the young engineers also work in the design studios, electronic and measurement laboratories and they use for solving the tasks more than 15 different software tools.

After the roll-out of the racing car the students start testing the systems and components, and adjust the performance, primarily the vehicle dynamics, using modern on- and off-board tools. The signals acquired with the telemetric system are saved onboard and evaluated later offline with Matlab® or Diadem®. Supported by industrial sponsors they drive the car on proving grounds. The aim is to be perfectly prepared for the competitions.

The SAE ® competition consists of two event packages: the static events and the dynamic events. During the static events the university teams have to defend their technical solutions, to explain and present the cost and manufacturing report, Figure 10, to convince the judges of their design concept. In the dynamic events the vehicle dynamic characteristics are proved, Figure 11.
The aim of each team is the winner's rostrum. There is only one real gratification for investing more than 40000 hours of work, sleepless nights, frustrations and euphoric feelings, defeats, ups and downs, doubts and hopes – the place on the winner's rostrum.
Conclusions

The second phase of the 3-Phase Multi Subject Project Based Learning Method is a very important milestone in our vehicle engineering course of study. Working on research projects from the concept to the product presentation the students develop essential skills they will need later in their professional life. The students steady the feature to be responsible for and to have ownership of the results of their work. The research projects encourage the students to be innovative and to work in a team.

In this work we presented one variant of research projects for undergraduates – the main task is the design and manufacturing of a small racing car within the SAE® contest. The students have excellent possibilities to apply technical and management knowledge and to learn across large curricular areas, connecting new learning to students' past performances. The faculty advisor and the supervisors are more mentors than teachers. The assessment is performance-based and the evaluation is much concentrated on the developing and solving methods than on the final results.

This project work provides students to conceive, design, fabricate, and compete with small formula-style racing car so that the young engineers are challenged to prove their knowledge, creativity and imagination. The end result is a great experience for young engineers in a meaningful engineering project as well as the opportunity of working in a dedicated team effort. The engineering students and graduates are also exposed to marketing, time management, project management, team building, budgeting, presentation skills, and other management issues. Through Formula Student, they develop experience, skills and professionalism as “hands on” engineers, with a keen awareness of the often competing pressures of performance, cost, safety, reliability and regulatory compliance. The benefit to students is immense and is good experience for newly qualified engineers preparing to enter a career in motorsports, the automotive industry or many other areas of high performance engineering.

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Bibliography

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