A Large Scale Problem Based Learning inter-European Student Satellite Construction Project

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A large scale problem based learning inter-European student satellite construction project

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Abstract

This paper describes the pedagogical experiences and lessons learned obtained in a large international student experiment:

- Build and launch a satellite within two years time frame with students from a universities all over Europe.
- Develop your own cooperative structures.
- Students may be forced to obtain skills on the fly as needed.

From a teaching angle this can be viewed as a very complex Problem Based Learning (PBL) experiment.

ESA (European Space Agency) Education Office launched January 2004 this rather ambitious project: Let students from all over Europe build a micro satellite within 18 months from design to launch – today claimed as the the fastest satellite construction ever.

The project is in details described at http://sseti.gte.tuwien.ac.at/WSW4/express1.htm.

More than 150 students from more than 14 universities all over Europe were participating in the development and construction of the SSETI EXPRESS. The satellite was successfully launched on October 27th 2005 (http://www.express.space.aau.dk) and was in full operation the first 10 orbits until a power system failure occurred. We and ESA view the project as very successful. From the beginning not many did believe in it.

AAU and PBL the starting point

Aalborg University (AAU) has a long tradition for Problem Based Learning at all three faculties since the birth of the University in 1974.

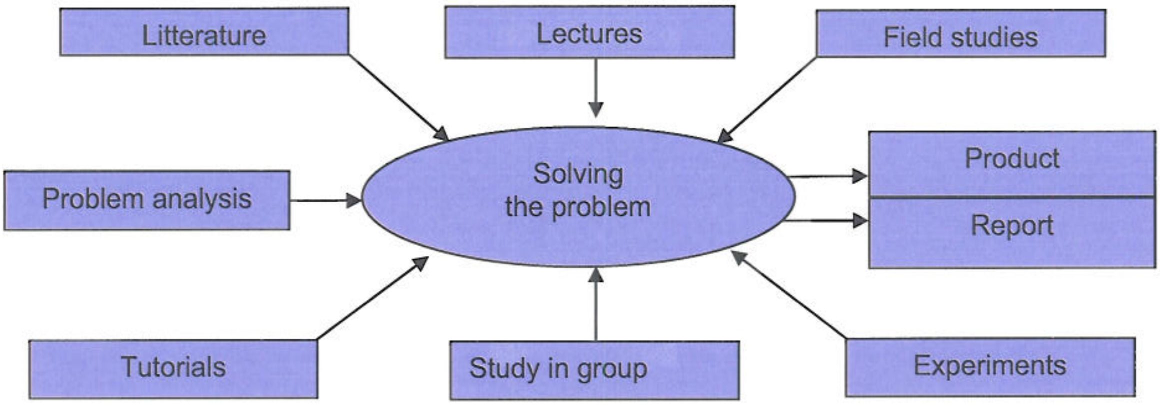
Within the engineering education skills are obtained by a combination of traditional lectures and group based project work with guidance and supervision from scientific staff.

The Problem Based Learning (PBL) paradigm is the cornerstone in education of engineers at Aalborg University. In fact, the entire educational structure of the university – at all three faculties - is based around project organized PBL. The students have an increased responsibility for their own learning – as individuals and to some extent on group level - by working in project groups. This requires the students to cooperate in carrying out the project work and communicate the curriculum between them. This teaching method yields higher level of reflection and deeper understanding [1,6] and at the same time learning to "work like an engineer". For a detailed description of the AAU implementation of the PBL model see [2, 3] or visit http://www.puc.aau.dk.

In general the PBL is implemented as follows: Students spend half of their (nominal) time working in groups focusing on solving a specific problem, and the other half on more traditional lectures. Each semester the students at own initiative form groups of typically 3-6 students. In the group they must select a project from a pool of proposals, which they will then work on during the semester under the supervision of a scientific staff member. Each of these groups get and a supervisor and an office of their own assigned for the project. All their study activities are carried out within the group. The students are supposed to be at campus 35-40 hours a week – like a "normal job" and in addition to that preparing for lectures. In this very close living the students are supposed to aide and support each other – and they do.

To ensure a certain education the project must fulfill some educational demands based on themes for the individual semesters. The specific problems, the groups work with in their project, can either be suggested by themselves, but most likely it is suggested by a scientific staff member, often in co-operation with industry. The students carry out the projects all the way from problem formulation and analysis, through the problem solving, and to the final result which is an 80-200 pages report and for the engineer students, a prototype of the system and technical documentation for what they have developed. The principle of the project work is shown in principle at figure 1.

Figure 1: A schematic over project activities.



At http://www.esn.aau.dk/english/UK_index/index_uk.html is our study structure for electronics and information technology at AAU – the homeland of the authors.

This organization of the education system has proven to be very rewarding for the graduates, and it is very popular with the students themselves, who prefer real life engineering problems compared to hypothetical, academic problems and lectures. This has lead to a highly beneficial cooperation with the local industry as many student projects are proposed by companies. Our students are examined within the same rule set as other Master Educations in Denmark. Our rating is as least as high as the others. 75% of the Master students graduate after 5.2 year(nominal M.Sc. study last 5 years) compared to 25% for a competing Danish educational site.

Problem Based learning for building Student Satellite Programs

The typical engineering projects at AAU are structured for solving a specific problem within the duration of a single semester, and cooperation with other groups is seldom. The hardware built by the groups, and used for demonstration of concepts at the project examine, is at the prototyping level for "proof of concept" use, and seldom finalized to more than a functional prototype.

Building satellites is a massive extension of a standard one semester project.

It differs at least as follows:

- Duration more than one semester
- Cooperation between different groups
  - At different semesters
  - From different specializations (ex. electronics, IT, mech, communication,...)
- Not building a "proof of concept" but building a high quality spacecraft

- High level of
  - Documentation
  - Testing
- Putting the satellite in orbit
- Economy: 1 kg in low orbit cost US $40.000 just for launch

It is a requirement that a satellite is built and launched, which introduces a number of problems of implementing a satellite project within a PBL framework. A single group cannot be expected to design and build an entire satellite within one semester. It is necessary to involve several groups, from different semesters and institutes, for the duration of a number of semesters. Some groups are expected to be involved in only parts of the project, as tasks finalize or new tasks are proposed to new groups. Building of the satellite will take more time than justified by a normal student project.

This method requires extensive work in management of the projects, maintained jointly by the students and staff members.

A challenge for the scientific staff is to impose guidance on the project. In a normal PBL based project running a semester the rules are easily identified and the scope is rather limited.

The students are carrying out these normal semester projects under close supervision from their supervisor.

In contradiction the management and supervision roles of the scientific staff in the satellite project is reduced by purpose for fullfilling the intention that the students are in control of the project. The University staff (professors,...) conduct what we have defined as "*Invisible management and guidance*". The purpose is to be NOT in control of the project but be ready for guidance, supervision and in seldom cases more traditional management if the project comes in very deep trouble. This gives the students responsibility for *their* project.

The purpose is not to reduce the workload of staff but to let the students mature within the process. It is no secret that many frustrations – like different interpretation of workload or technical problems/challenges, ... - can be very frustrating, but for the most the students reach solutions by themselves – as intended. A very valuable experience and learning.

Satellite Structuring

A satellite is organized in a number of subsystems (like pro satellite development). Some of the main subsystems are: power supply, main control computer, payload, maneuvering, communication and ground station. To hav a functional and efficient management each subsystem group appoints a delegate – a system engineer – which participates in the steering committee. A second seat in the committee is given to each group, occupied round-robin amongst the remaining group members.

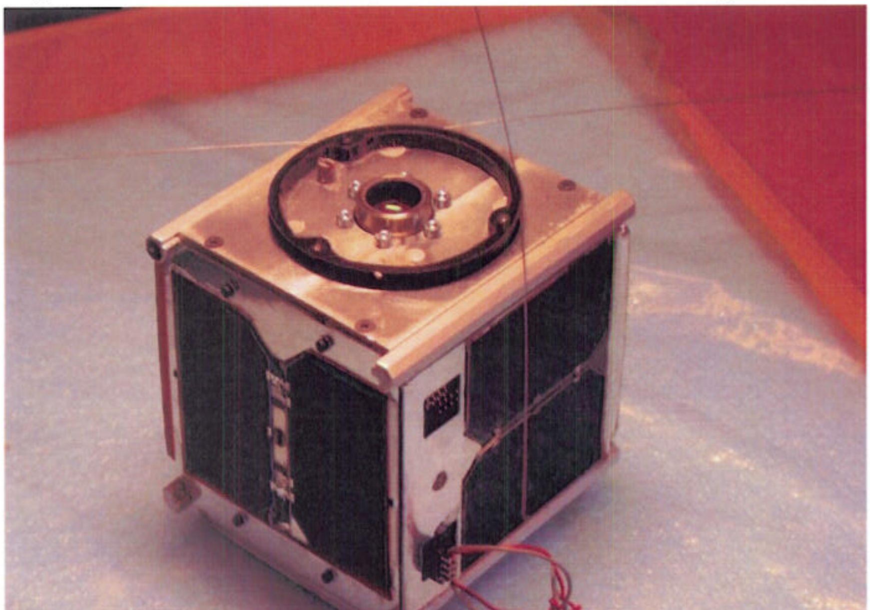
This ensures consistency and continuity in the steering committee and ensures that all students are included in the management tasks, whilst limiting the number of people present at meetings.

At AAU, this structure is mainly implemented in the first half of the project, since experience shows that the number of groups involved, and also the sizes of the groups, tend to decrease over the project period. This is due to the fact that tasks at the finalization of a satellite, i.e. implementation, integration, and testing, are not tasks which semester projects can be based on within the curriculum. Hence these tasks are typically done by students in their spare time, motivated by the prospect of launching the satellite into space. From an educator's point of view, this is an important benefit of PBL in space education, as the extra work put in by the students, also gives the students relevant hands-on experience, without compromising the scope of the curriculums.

The steering committee ensures the maintenance of necessary system engineering documents, such as user and system requirement documents, time plans, milestones, etc. In the beginning of a satellite project, the main part of these tasks is handled by staff. As the project progresses, the maintenance responsibility of the documents are passed on to individual students in the steering committee. This is done to prevent work overload of the students at the beginning of the project, since project management is a comprehensive task, and the students have courses to follow, and sub-systems to design on top of this work.

Students at AAU did succeed to build their first satellite in the period 2001-2003 which is shown in figure 2. The satellite was in orbit June 2003 and was in successful operation for several months (http://www.cubesat.aau.dk)

Figure 2: AAUs first CUBESAT 10cm x 10cm x 10 cm 1 kg.



PBL and building an international student satellite ESA's SSETI EXPRESS.

European Space Agency (ESA) has an obligation to spread interest and knowledge for space. For that purpose ESA Education Office has several activities ranging from public schools to university students. Activities range from visit from school children to building student satellites.

Compared to normal PBL education activities SSETI EXPRESS may be regarded as a very extreme high risk project in context of the project and the variety of students involved. Such a large scale "experiment" has not being tried before.

The project was a student driven project with student project responsibility adding at lot of international experiences and project management skills to the outcome of more traditional one semester, single group projects. The ESA Educational Office associated a technical coordinator and an administrative coordinator with the project – two very important anchor persons.

ESA Education was formal in charge of the project and individual students NOT universities were enrolled as participants. More than 150 students from 14 universities were participating in the whole project period or parts hereof. The main idea of enrolling students instead of universities was to let the student be in control and not the universities.

Some of ESA's criteria's of success was:

- Get engineering students interested in space.
- Get engineering students all over Europe to meet and cooperate.
- Having cooperation despite peoples different physical location.
- Have a design of a satellite to be developed.
- Get a working model.
- Get a flight model build (the one to go in space).
- Get a satellite up in orbit.
- Operate satellite from earth.
- Get attention from children, students and population in general.
- Get it all done in a time frame of 18 month.

It is interesting to observe that success was not only a matter of flying a satellite but mainly to gain attention for space and space education, and to have students cooperate over the borderlines in Europe. Participation in a successful large scale inter cultural problem based engineering project includes a variety of engineering disciplines as mechanical construction, communication system, power supply, attitude control system, onboard computer systems, software, ground station and payloads, all to be covered by students from universities using different educational models. In addition due to the number of involved partners, economics and physical distances many of the students never meet in real life, implying that cyberspace communication technology was vital within the project.

The combination of the PBL educational system and the satellite experiences within the Department of Control Engineering made it very relevant for our students to participate in the ESA student satellite SSETI EXPRESS. Our year long experience in PBL and the very non formal way "Scandinavian" of real cooperation between students and teachers/professors provides the students with the necessary skills for such a cooperation.

The effect of PBL trained students in an international project

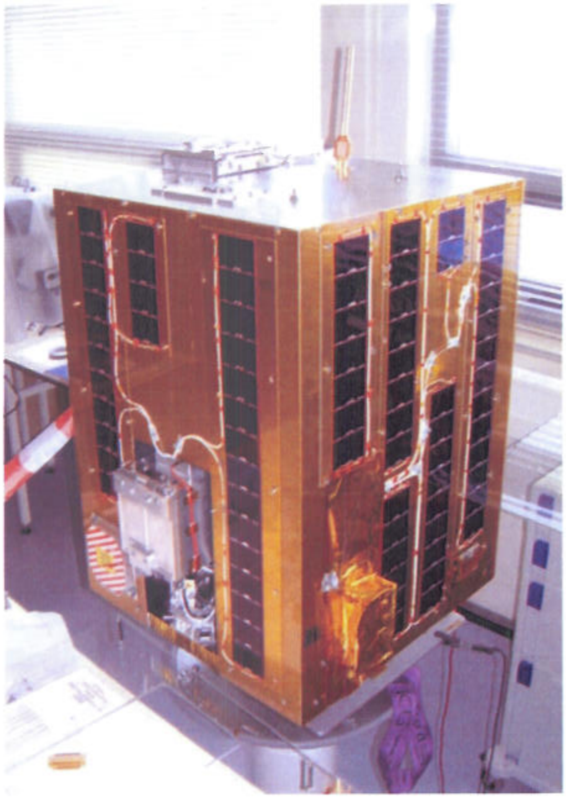
From the beginning the AAU students were responsible for one of the subsystems, the attitude control system. The AAU student involvement changed very much during the project. This did change very much over time. For a number of the participating students from around Europe it seems to be very difficult to do this very complex project work and project cooperation. For many of them SSETI EXPRESS was their first project ever. Many engineer education institutions around Europe still stick to a traditional academic method of learning – mostly based on lectures and exercises.

In contradiction to that the students from AAU had very high benefit of their PBL skills. They were able to obtain an overview of the whole project. From being responsible for only a minor part of the satellite they did overtake work and subsystems from other students which realized they could not perform within the very limited time frame. They ended up as a major player in system management and system integration, they delivered four subsystems including the main computer and the communication system and finally they developed two ground stations, one at Aalborg University and one remote controlled ground station at Svaldbard in the North Atlantic. The launch operations were conducted at the local "Houston" Ground station in Aalborg.

A number of problems were identified:

- Many universities did not have any tradition for PBL or doing project work as part of the study – e. g. the students was not familiar with working like real engineers.
- Many universities did not try to incorporate the students participation in the curriculum.
- There are very broad span in cultural behavior across Europe. But all students were trying to perform to their best.
- It didn't fit to a standard semester - 18 months for the satellite project compared to 5/6 months for a "normal" semester project.
- Difficulties in integrating the tasks in the education at the traditional universities.
- The complexity in the satellite project is extreme compared to a standard PBL projects.
- The project had to end up with a real tested product at the launch date!
- The last phase: finalization and launch campaign is very difficult to fit into the study curriculum.

Figure 3: SSETI EXPRESS flight model



Effort Distribution

A normal student project has a distribution in the workload roughly as follows:

- Obtaining knowledge 15%
- Problem Analysis 25%
- Problem definition 10%
- Design 30%
- Implementation and test 20%

The construction of a satellite is more like:

- Obtaining knowledge 10%
- Problem Analysis 10%
- Problem definition 10%
- Design 15%
- Implementation and test 55%

This does imply that the students use less time of the first bullets but rather that much more working power is put into the project.

This can have some curriculum problems if all the time used by the students has to be part of their education. In real life they use much of the private time, holidays etc.

Lessons learned

It is our honest believe that engineering students which are following a PBL project based study has skills not obtained at more traditional engineering education institutions. It is natural for them to work as/like an engineer. Their capabilities within project organization and structural analysis etc give them many advantages in a complex project like SSETI EXPRESS. It has also been interesting to observe that the other students recognize these qualities and give them space in management as well as at technical level.

A negative side effect has been that our students has been among the most engaged and hardest working at the project. This may have an impact on their "normal education". But the university has seen this as an alternative and very promising way of obtaining curriculum. This is also a necessity if we as responsible teachers shall "let" our students participate in such projects.

From a student perspective this is the ultimate way of learning to be an engineer. The price is the time used – which can be many hours.

In that context it can be argued that for many of the participating students such a project becomes a mixture between education and a hobby.

After the launch the project has been acknowledged from ESA top leadership as a very high quality project, which has paved the road for continuation of such projects in ESA regi.

We are already on way with the next AAU student satellite AAUSAT:
See http://www.aausatii.aau.dk

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