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What kind of project in the basic year of an engineering curriculum

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Objectives of classical projects are usually to apply and synthesize knowledge acquired during courses. Such projects are therefore result oriented. However, within the framework of project-based learning as developed in the new engineering curriculum at Université catholique de Louvain, the project should be oriented towards the acquisition of new knowledge and competencies. In this context, the result of a project is the solution (e.g. a prototype, a contest) and the learning process. Such projects come before (or simultaneously with) the courses and are used to contextualize the concept. The two types of project have different objectives, characteristics, assessment and tutoring principles. They therefore have different fields of application.

1. Introduction

Even though our graduates are certainly valued by industry, a lingering sense of dissatisfaction has taken hold of our faculty for a number of reasons: low student motivation, high drop-out rate, shallow mastery of course material, low retention rate, little demonstration of higher-order skills, too little initiative or autonomy. A significant portion of our teaching staff was less than happy with the outcome of our educational process: for all the effort expended (both by teachers and by students), the level of competence achieved after years of study is globally disappointing, certainly in the earlier part of our 5-year curriculum (Aguirre *et al.* 2001). Based on our perception of the failure of classical curricula to satisfactorily address some of the essential issues in engineering education and fuelled by a growing lack of motivation expressed by (some of the) staff and students alike, a multi-disciplinary team within the Faculty of Applied Sciences of the Université catholique de Louvain set out to approach the design of a new curriculum for the first 2 years of the programme.

One of the first tasks of this group was to find out whether our perception was true or whether it was isolated. It is very difficult to answer this question because we do not have an Accreditation board in Belgium to assess the quality of our programme. But it appeared quite rapidly that our feeling was not isolated. When managers from industry are asked what they think about our students they answer that they appreciate their scientific level but would like to see more emphasis on other non-scientific skills such as the development of team spirit, problem-solving capacity, autonomy, capability to learn new topics, and so on. They strongly encourage the development of active pedagogy. Such views are not very far from the Accreditation Board of Engineering and Technology (ABET) point of view. The trend in engineering education developed

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by the ABET is to encourage integration of design and holistic integration of 'soft' and 'technical' skill encompassing academic knowledge, civil responsibilities, and life skills consistent with the engineering profession (Nagchaudhuri 2001). Twente University in The Nederlands is of the same opinion. In 1994 the Faculty of Mechanical Engineering started a new programme bases on project-based education arguing the 'decrease in student progression and the insufficient mastery of skills such as problem solving and communication' (Peters and Powel 1999). Finally it should be said that active learning meets the learner's interests and promotes learning motivation.

After having identified the requirements, some of us spent some time finding out as much as we could about the essence of our actual business: learning (as opposed to teaching). It came somewhat as a surprise that very few of us had actually tried to understand what learning is all about, let alone taken the time to study actual learning theories. Many of us assume that learning is simply what a student does when exposed to lectures. There was little motivation for detailed, in-depth comparison of the various learning theories, but we were quickly attracted by the *socio-constructivism* (Novak 1998), which turned out to be the *learning theory*, that was the most appealing for a majority among us. 'From the constructivists' perspective, knowledge resides in the individual and cannot be transferred intact from the head of the teacher to the head of the student' (Wallace and Louden 2002: 191). Combined with the notion of *situated learning*, it claims that new knowledge is acquired by building upon and transforming previous knowledge (not by simple transmission) and that learning works best in communities of learners. It should be pointed out that 'It is not really important to find 'the best' learning theory at all: the important factor is to agree, collectively, upon such theory, since this provide a common framework to evaluate ideas and proposals with a common yardstick and avoid lengthy conflicts of opinions'. (Aguirre *et al.* 2001).

There exist many ways to organize learning within the framework of a given learning theory. After additional reading, experiments (Wertz *et al.* 2000, Raucent 2001) and several visits to foreign institutions both in Europe and in the US, our preference went to active, self-assessed, self-directed, interdependent, small group, partially tutored project and problem-based learning (P^2BL), which is our own instantiation of the principle of 'learning by doing in small groups'. The design process of our new curriculum based on instructional engineering (Doré and Basque 2002) is described in Aguirre *et al.* (2001). Active learning is the central principle of this model: students are continuously exposed to activities, which require active participation.

The new programme was introduced in 2000–2001 for the 350 first-year students. The groups (composed of eight students) are constituted randomly at the onset of each trimester and work on problems (two per week) and one project (one per trimester). A problem is a short-term mono-displinary activity. Typically each student spends 8 h per week on each problem, which is organized and supervized by specialists in one discipline (e.g. mathematics, physics, etc). Problems are designed and run in much the same fashion as in, by now 'classical', problem-based learning. On the other hand, projects are long term inter-disciplinary activities (about 80 h, four European Credit Transfer System (ECTS) work for each student). The project grade contributes 30% towards the student's final grade.

We have a very long experience of projects in our faculty. We have conducted project for more than 20 years in the fifth year of the curriculum and information on such projects may be found in Raucent (2001) and Raucent and Johnson (1997). But when we had to prepare the first project, (i.e. the project that young students would have to solve during the first semester of their curriculum), we faced a major problem in defining the objectives of the project. When designing the curriculum, it was decided that at the end of the first project 'students should be able to model the kinematics of a vehicle and write a simple JAVA software'. In order to reach such a goal, a first draft of the project was drawn up: students would design a mobile robot, develop its kinematic model and write a JAVA software to move a prototype made from LEGO© Mindstorms.

The design of the project was entrusted to a team of specialists with an extensive experience in student projects on vehicle design. The team been responsible for many projects, among which were designing and building a small robot able to find its way through a maze (project for second-year students), (see figure 1) and designing and building a small robot able to perform an obstacle race, (see figure 1). Based on the team's knowledge and preliminary experiments, it was proposed to design a small micro mouse LEGO© robot able to move through a maze. Mindful that the LEGO© Mindstorms system is not accurate enough, it was suggested to use an external sensor (e.g. a contact sensor to follow a wall). A stormy discussion then arose between the specialist in robot design and people in charge of the disciplines (mathematics, computer sciences, physics) about the use of such an external sensor. The first argued that without the external sensor the project would not be realistic, and less attractive for the students. In addition, external measurements added an interesting objective to the project. The others argued that regulation and control are not part of the project objectives, any new objectives would sidetrack students from their main semester objectives: learning mathematics, physics and computer science. In addition such new objectives would introduce extra work and probably specialization within the groups. Such a specialization is not a problem in itself, but has to be controlled and a special time for sharing information should be placed in the timetable. It would be very difficult for the young students to manage such time sharing during the first project.

In fact, such discussions took place during the preparation of the sixth project of the curriculum. There was clearly a need for a clarification of the objectives and characteristics of the project we wished to introduce into our new curriculum. In particular, we had to answer the following questions:

- Should the project and its objectives be realistic?
- Should the project be a training ground for a future engineering job, with actual constraints?

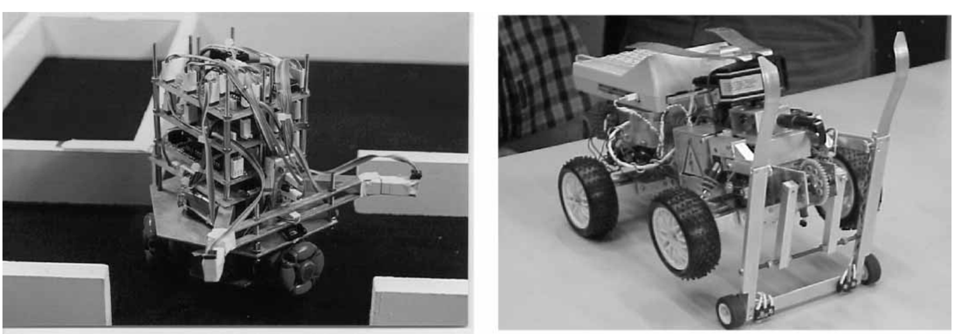

Figure 1. Examples of previous projects.

- May the project introduce specific objectives?
- Does the project require only using knowledge acquired in the previous semesters?
- Should the project have a strong connection with the semester's disciplines?

This paper discusses the principle of the project in our curriculum and emphasizes the difference between what we call 'pre-project' and 'post-project'. In the setting of education, all projects should to be learning projects, but we use the term pre-project to make it clear that the objectives of such a project is to contextualize and acquire new knowledge and competencies, and not merely to demonstrate an ability to apply previously acquired capabilities.

2. Post-projects

For many years, the project has been used as a learning method to prepare students to work by project (to learn some methods and the reasons for using them) and thus to prepare them for their future job. Many papers present industry-inspired projects: for example, Hughes (2001): 'The culminating major design experience is a critical element in students' preparation for professional practice'. According to Gol *et al.* (2001), 'Students compete for participation in such projects; they perceive these to have high relevance to industry requirements, and their career choice and development prospects in addition to providing documented substantiation for potential employment, particularly with a participating industry partner'. Such projects are usually organized at the end of the curriculum and are disconnected from the other courses. In other cases, for example in architecture and industrial design, programmes may be built around the project and it thus becomes the centre point of the curriculum. This is the case when the project aims to combine several fields, such as in mechatronics, which combines mechanics, electronics and computer technology (Grenier *et al.* 2000, Nagchaudhuri 2001). Another objective of introducing the project in an undergraduate curriculum is student recruitment. 'Clearly the engineering program today has become less exciting to the student. For many, this structured curriculum is simply boring and difficult especially when courses taught are as stale as the textbooks read . . . A large-scale micro mouse project can easily draw public attention, as we have experienced, and may become an effective tool for the outreach program' (Chen and Chung 1995).

However, introduction of projects during the first year of an engineering curriculum is more recent. It was usually admitted that a curriculum should to start with the basic sciences such as mathematics and physics. Knowledge acquired during the basic year will be applied later in particular cases, meaning that the project was reserved for later years. For some time, this mentality has moved towards a new concept of education. Today it is widely admitted that the project has a major role to play during the basic year of the engineering curriculum. For example, Wallace and co-workers reported on integrated design project within an English undergraduate curriculum, (i.e. a 3-year bachelor programme). According to them a design teaching programme should include: (1) a considerable amount of 'learning by doing', (2) a clear and consistent model of design process, and (3) a conscious effort to apply and integrate the fundamentals taught in other subjects (Wallace *et al.* 1997). As a consequence, they introduced a second-year project built on the engineering sciences taught during the first year. This project is therefore principally based on the application and synthesis of previously learned topics. Of course it follows that other objectives should be included, such as an introduction to teamwork. It should be pointed out that students are placed in a 'real life' situation with limited resources and that competition is used to increase motivation. The aim of the project 'is to give students as realistic an experience of multidisciplinary systems design as possible, i.e. a challenging technical task with limited resources and tight time scale' (Wallace *et al.* 1997).

2.1. Objectives

The main post-project objectives may be summarized as:

1. to give students a realistic experience of a multidisciplinary problem;
2. to give students a challenging task;
3. to train them to work in a realistic industry-like environment;
4. to train them in team-work;
5. to synthesize and apply knowledge to particular cases; and
6. to learn the design process.

2.2. Example of project

Figure 2 presents example A of a prototype built by second-year students within the framework of a project (previous curriculum). The assignment was 'design and build a low-cost prototype of a small vehicle able to cover a predetermined distance over a given road profile'. This project is fully described in Raucent and Johnson (1997); it focuses on the relation between creativity and modelling, experimentation and simulation. The principal steps can be summarized as follows.

- Selection of appropriate techniques to store energy: students have to choose among pressurized gas, a flywheel, a spring, and so on (only mechanical methods are allowed).
- Vehicle design: students have to propose solutions and build a model of the best one using wood or paper.
- Prototype realization using a 'Meccano©' set containing beams, screws, gearing, and so on.

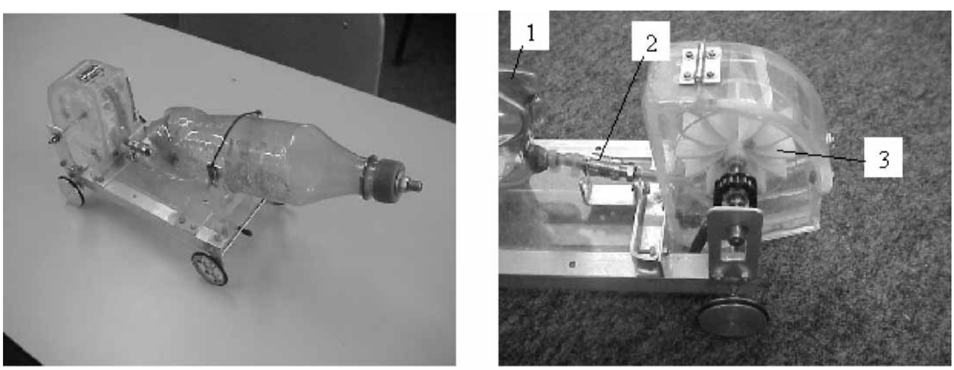

Figure 2. Example of post-project.

- Vehicle modelling: students propose a dynamic model of the vehicle. Some experiments are performed on the prototype in order to evaluate particular parameters such as friction coefficients, stiffness of a spring.
- Performance assessment: a MATLAB© simulation is used to predict the performance of the vehicle, and in particular the distance that the vehicle will cover during the final test.
- Final test: a competition is organized over a contest track.

Figure 2 shows the prototype built by one group of students: a soft drink bottle (1) contains water under 7 bar air pressure. The air pushes the water through a small pipe (2) onto a paddle wheel (3), which transmits the torque to the wheels.

2.3. Characteristics

Motivation and statement. A contest is very often used in the post-project as a means to: (1) motivate the students, (2) impart a good sense of reality, (3) train to work in simulated but realistic industry-like settings of limited resources, time pressure, and high competitiveness, and (4) teach the importance of co-operation and teamwork (van Breeman 1997). These are the arguments that we used to choose a contest in example A. But, as our goal was not to start a fight between students, we chose a 'race against the clock' where the best team is the one that most accurately estimates the distances travelled. Before the test, each team indicates on the track the estimated travel distance. This means that there is no direct competition between students and that we emphasize the fact that the objective is to model and simulate the vehicle performance. Students' motivation stems from the fact that the objective of the project is well defined: you can only be the best group if you propose the best performance index (i.e. the best estimation of the distance travelled).

Apply knowledge. In example A, students can only use knowledge acquired during their first year, plus the knowledge that they acquired in the previous semester—they have no other knowledge available. The students have to use previously acquired capabilities and apply them to their problem. The knowledge to be applied is usually well defined (e.g. the dynamic model of a vehicle). This is why we call it post-project. Figure 3 illustrates the relation between knowledge acquisition in courses and knowledge application in the project.

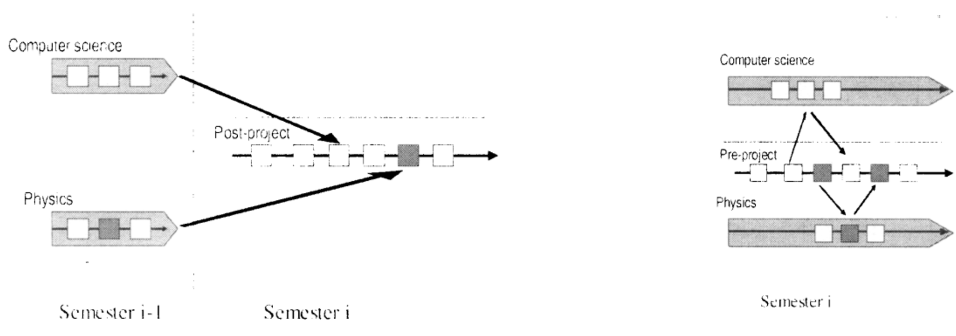

Figure 3. Project agendas.

However, some freedom is allowed. This does not mean that students may chose the knowledge they wish to use, but that they have to use what is required by their project, and these requirements may depend on their solution. For example, in example A, students have to model the dynamics of the vehicle and the chosen energy storage technique whatever the solution. As a consequence, some students have to model a spring, others a flywheel or air pressure, and so on.

Assessment. Project assessment is always a very difficult matter: should we take into account the process or only the final result? Do we have to evaluate the students individually or the team? What happens if the rest of the team rejected a student? Do we have to take into account the enormous amount of work performed by the team or only the result? and so on. There is no common answer to these questions. However, our experience in post-projects shows that the members of the jury are usually more interested in the final result: the quality of the solution, the quality of the report and/or oral presentation, the contest. The other aspects such as project process, team work, individual work usually have less importance. This is not specific to a post-project, but to the fact that such projects are result oriented: students and professors focus on the result. A consequence of this is that it strengthens the students' feeling that only the solution matters. It is well known that students will do what is needed to score a high grade at the assessment.

We experimented several solutions to avoid this problem. In the example, the students submitted their report on the day of the contest. Then, based on the contest result, they wrote up, for the following week, 2 pages about their performances: Why is the estimated distance travelled close to (far from) the measured value? What parameters are not well identified? What are the problems in the simulation software or the model? How can we improve the design of the vehicle or the energy storage method? These two pages are used to initiate the discussion with the jury. The objectives of this discussion are to try and evaluate how well the students have understood what they used to solve the problem (to win the contest).

Main characteristics. We can summarize the post-project characteristics as follows.

1. The problem statement arises from an actual problem. However, small adaptations may be required to limit the difficulties, reduce the amount of expertise required, reduce the time required, and so on. To put it in a nutshell: make it feasible by students.
2. The statement clearly indicates what the result expected is. This does not mean that the solution is already known, but that the project result is specified, (e.g. build a prototype and win the contest). This result may be physical, software or a model. A criterion will indicate that the project is finished and is a success.
3. From the very beginning of the project, students and professors aim to reach this result. As a consequence, the project is very much 'result' oriented.

3. The project in our new curriculum: the pre-project

The first experiments on of project-organized study were performed in Scandinavian countries; (see, for example, the Copenhagen Engineering College (Vinther 1979) or Aalborg University (Hjersdam 1994). The curriculum is based on a long-term project that may take up half a semester. In Aalborg, they speak of project-led education to make it clear that the project is the centre of the learning process. In such a project the objective is not the 'result' (e.g. the prototype, the model, etc), but the competencies acquired during the project.

Professor and student attitudes are completely different. For example, during the project presentation students must present their result and which learning objectives they have reached. Members of the jury ask questions on the project and on knowledge acquired during the project.

3.1. Example

Figure 4 shows another example of a prototype built for another project (example B). The assignment is 'Design an autonomous vehicle able to draw a white line on a playground (football, etc)'. This project is proposed during the first trimester of the first year of the new curriculum (i.e. at the very beginning of the curriculum). The main steps may be summarised as follows.

- *Problem clarification*. The students have to choose which playground (football, rugby, etc.) and the type of robot program (how many different playgrounds, what kind of colour, etc.). They must prepare a small document describing the function, the performances and constraints of the vehicle. Finally they propose a test trajectory for the trial run.
- *Conceptual design*. Students have to propose solutions; we ask them to draw the principle of the solution and to build a model first from paper then from wood (see figure 4).
- *Vehicle modelling*. The students have to model the solution: write the kinematic model of the robot and model the test trajectories (decompose it in a simple geometric paths such as straight lines and circles).
- *Vehicle simulation*. Based on the kinematic model, students write a JAVA simulation software of the test trajectories.
- *Validation*. The students build an operational model of the robot using Mindstorms (by LEGO©) and write the software to control the robot over the

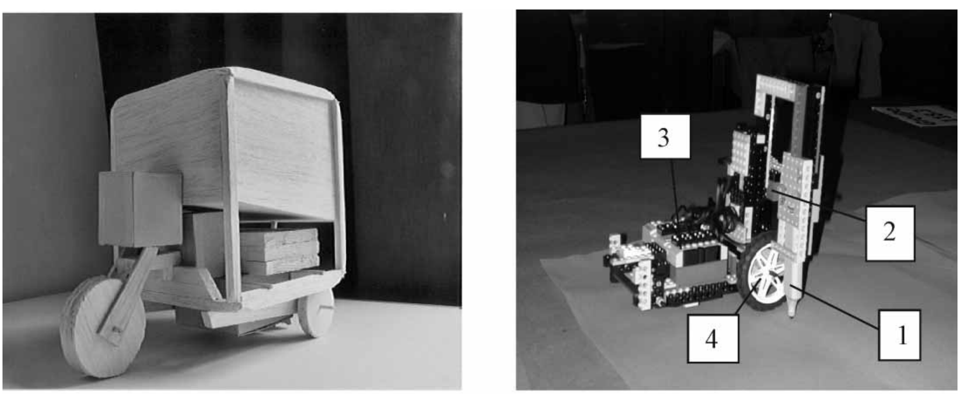

Figure 4. Example of model and prototype built within the framework of the new curriculum.

test trajectories. The Mindstorms package contains building elements, motors, actuators, gears, and so on, and a processor that can be programmed via a PC.
- *Trial run*. At the end of the project the students present their robot and propose a trial run of the robot over the test trajectory.

In the example shown in figure 4, the painting equipment (for the actual robot) has been replaced by a pen (1) on the LEGO© prototype. This pen is moved up and down by the motor (2) controlled by the Mindstorms processor (3). The processor also controls the speed of two wheels (4). The robot moves in a strait line if the two wheels turn at the same speed and rotates if the wheels turn at different speeds. The mobility of the robot is similar to that of a wheelchair.

3.2. Discussion

At first sight the two projects, examples A and B, seem similar. Looking at figures 2 and 4 and at the project's mains steps, no major differences appear. In fact both projects:

- are attractive and afford great freedom to the student;
- are inter-disciplinary projects (mathematics, physics and computer science are involved);
- are realized by a small team of students working under the supervision of a professor (a tutor);
- promote student creativity;
- promote connection between design, modelling and simulation (in both case students have to model and simulate the vehicle before the final test);
- lead to the realization of a prototype, one using classical Meccano© and the other using LEGO©; and
- end with a competition (which is a great source of inovative ideas).

But, on second sight, if we look more closely at the process, some major differences may be pointed out. The first project takes place after the courses on dynamics, mathematics and computer science. The agenda is: students attend the courses then they try their hand at application and synthesis in an inter-disciplinary project, see figure 3a. On the other hand, the second project starts before the courses and should contextualize and promote learning, (see figure 3b). Some objectives are directly learnt in the project, which is why we call it pre-project.

In example B, a multidisciplinary team of professors prepare the project. In addition to the classical project objectives, such as team-work capabilities and designing practice, we find some disciplinary objectives such as a 'student should be able to model the kinematics of a vehicle' or 'to write a software to simulate the robot trajectory', and so on. Such objectives are defined in close connection with the professors in charge of physics, computer sciences, mathematics courses, and so on. The project contextualizes and, if necessary, the course provides additional details, adds some theory or establishes some connections with other concepts. For example, during the project the students have to model the kinematics of their vehicle. In the case of a wheelchair-like structure, the students have to write the relations between the speeds of the two wheels and the trajectory of the vehicle (longitudinal and rotary speed). The problem is introduced in the project, then some activities, such as problem-based learning, are organized by the physicist in order to understand the 'rolling without slipping condition', and so on. Then the competencies are applied within the framework of the project.

Finally, example B promotes design process learning. During the first steps (problem clarification and conceptual design; see section 3.1), students follow a process based on Cross (1983) design methodology. They learn to write product requirements to propose and select principles and to sketch a draft of the solution.

3.3. Objectives

In our opinion, objectives 2, 3, and 4 of a post-project (see section 2.1) are also applicable to a pre-project, but objectives 1 and 5 should be re-written as:

1. to acquire a methodology to work on a multidisciplinary problem; and
5. to contextualize and acquire disciplinary objectives through solving a project.

In fact, objective 5 is the key point of the pre-project. It is no longer a question of applying knowledge, but of acquiring new knowledge during the project.

3.4. Characteristics

Statement. Both projects A and B end with the realization of a vehicle prototype. But in example B the prototype is only a part of the result. In fact, the project statement makes it clear that there are three major objectives:

- to design of a robot able to draw a white line (the solution);
- to learn and practice the design process; and
- to learn, understand and apply some disciplinary concepts such as 'rolling without slipping condition'.

The statements also stress that the prototype is only a means to validate the design, the designing process and to assess that the concepts have been correctly understood. In other words, the prototype is not the result of the project, but only a way to show that the three objectives (design, designing and learning) are reached correctly. The problem statement may or not derive from an actual problem. This is not crucial, and the problem is rather to find a subject that has good connections with the various disciplines.

Open or closed project. When preparing the project we had to face two opposing philosophies. On the one hand we wanted an open project in order to give the students enough freedom, as it is well known that this will increase their motivation. On the other hand we want a closed project in the sense that we wanted to be sure that all students would reach the disciplinary objectives.

According to Nielson (2000) and Kolmas (1996) there are three types of projects.

- *Closed project (or assignment project)*. Students will perform a succession of tasks, the problem is known, the methods are known, the solution may be known (i.e. the project and the subject as well as the methods are chosen beforehand). The major advantages of a closed-project are that education objectives are easily controlled. It is easy to ensure that the students have performed all subtasks if the project is split into well-defined sections.
- *Half open (or subject project)*. In this case only the subject is chosen beforehand. The problem and methods are partially known. 'In a half-open project there will

always be a number of objectives that the student can pursue. The supervisor should let the students choose according to their interests, and only intervene if they want to do something that is not in accordance with the curriculum of the particular semesters' (Gol *et al.* 2001).

- *Open-problem (or problem project)*. The students have all the freedom they desire. The problem is partially given; methods and tools are missing. Students will have to clarify the project statement and propose a way to solve it.

Open problems are more easily implemented in the last semester, and in particular in the final year project. Coming from a tradition of 'lecturing education' where the professors present the new concepts and know exactly what has been covered during the lectures, it was very difficult to imagine an open problem during the basic year. This is why our choice went towards partially tutored (P^2BL). We use projects mostly to develop interdisciplinary and longer-term (11-week) approaches, while problems are used mostly within a single discipline and during a shorter time span (1 week). Our hypothesis is that problems allow our students to delve in a more controlled way into disciplinary topics than projects, thereby ensuring that essential topics would not be merely glanced at. As a consequence, we can say that our projects are 'closed' regarding the learning objectives (learn through the problems) and 'open' concerning the solution objectives.

The project is open because the initial statement is very imprecise. During the first step, the students have to: (i) clarify project statements (which games, etc.), (ii) choose solution performances (what speed, etc.), and (iii) choose validation experiments that will be performed at the end (which test trajectory? etc.). In addition they have a lot of freedom in the solution they wish to propose. The only constraint is that they will have to prove that the solution is the best answer to their project statement. As a consequence, any time during the project each group will work on its particular statements and solutions. In particular, during the conceptual design step (see section 3.1), students are asked to propose alternative solutions to the problem and compare them using requirements defined at the clarification step.

Learning objectives and project definition. The key point of the preparation is to split trimester disciplinary objectives into two categories: project objectives (which will be learning, partially or totally, during the project), and objectives without any connection with the project. It is possible to build a project with many objectives but impossible to build it with all the objectives. In order to select which will be part of the project, 'way points' should be defined.

A waypoint is a sub object that students should acquire and that makes the connection between disciplinary objectives and the project. For example, the disciplinary objective being 'students should be able to write down the kinematic model of an object', many projects may be proposed such as 'determine the trajectory of a cannonball' or 'model a boat'. But if we define the waypoint as 'students should be able to use a rolling without slipping condition in a kinematics model', we impose that the object to model should have wheels. And the project statement becomes 'model the kinematics of a vehicle'. As a consequence, disciplinary way points give strong indications in project construction. However, this is not a linear process and, as for any design, the project design is a complex process that requires some experience. We strongly recommend performing some preliminary experiments.

Example B was based on two experiments, performed in the project of the previous curriculum. We simply modified the object of existing projects. In the first experiment we tried to analyse the link: design project (where students have to design an ‘electrical vehicle’ or ‘sundial’ or ‘sailing boat’, etc.) and physics. In the experiment we asked students to design a ‘fairground device’ and to set up its kinematic model. The key point of the students’ job was to clarify the statement, select solutions and draw the device, the last step being to model the device (Aguirre *et al.* 2000). The major difficulty encountered in this experiment was that the statement was too open and that students were allowed to design any kind of device, in many cases too complicated to model at their level. For example, during the first trimester they learned to solve single differential equations and not systems of differential equations, meaning that they could not model devices containing more than one degree of freedom. Based on this experiment, we decide to fix the ‘rolling without sliding condition’ as a way point. We therefore decided that the student should design a vehicle with wheels.

Connections between design and computer sciences were investigated via another project. We propose that students should ‘build a small robot able to find its way through a maze’. This project was inspired by the IEE Micro Mouse Championship in Lille in July 2000, (http://www.swallow.co.uk/contents/microm.htm). During the first semester, students have to design and build the robot using Meccano© sets and ‘home made’ parts. During the second semester, they write the programme that moves the robot.

For this experiment a technician developed all the electronics required (this was not a student objective). This was an important job and led to many small problems. The most important outcomes of this experiment were:

- to recommend the use of standard equipment and no ‘home made’ mechanics or electronics; and
- the objectives are too ambitious and students focus only on the result: the robot and the contest.

Once again this experiment was very important in clarifying the project. We decided that the students should first design a vehicle, then set up the kinematic model and simulate the model, and finally validate the model, and the programme on a Mindstorms prototype. Student should focus on the final prototype only after the modelling and simulation (we gave them the Mindstorms box after they finished the modelling and simulation tasks). We therefore defined three milestones:

- Problem clarification and conceptual design: presentation of a small report and model made from wood.
- Vehicle modelling and simulation: presentation of the kinematic model and the simulation.
- Trial run using Mindstorms: where the robot followed a predetermined trajectory.

Teamwork and tutor training. Tutors have a very important role to play. In a classical post-project, the student and the tutor focus on the result. Meeting is more a consultancy (i.e. the tutor answers students’ questions). In the case of a pre-project, the tutor cannot answer the students’ questions. The problem is that by answering questions a tutor prevents students from searching in the literature. We had students confessing that they did not open a book because their tutor gave them all the information. As a consequence students may be able to propose a solution but without learning and use theory and tools as 'black boxes'. In a pre-project the tutor is more a coach that a consultant, he gives more methodological information and tries to check whether all the students reach the learning objectives.

The tutor's role is a key point in the success of the project. Tutors should not directly answer students' questions. They should indicate where and/or how to find the information. An interesting discussion on 'to tell or not to tell' can be found in Wallace and Louden (2002).

Another task for the tutor is to supervize the students' learning and be sure that subtasks (sublearning objectives) have been performed by all the members of the group. Usually students are willing to divide the work into small tasks, this being the objective of good teamwork. But the 'dividing' should be well defined. The natural tendency is to distinguish between different tasks, such as searching for information, writing the report, drawing the figures, solving the problem, and so on. In a good pre-project, each member of the group should meet the learning objectives. This means that the 'dividing' should not be based on the different tasks, but on similar tasks: each student should learn the theory yet in different book then the group will compare the different models; each student should develop a different part of the programme but take into account the module connections, and so on. The role of the tutor is to be sure that the 'dividing' is well defined according to the learning objectives. This is a very difficult matter because the tutor has to move from a 'result'-oriented approach (where only the result has a value) towards a 'learning'-oriented approach (no matter what the result is). Tutors usually have a natural tendency to be 'result' oriented and therefore need to be trained in order to change their philosophy. In order to develop a good training programme we asked foreign professors, from institutions having a long tradition of project learning, to come and organize this training. We were very lucky to be able to rely on many training sessions organized with the help, gratefully acknowledged, of colleagues from Aalborg and from Delaware, as well as from our own Institute for Pedagogical Development.

Assessment. At all times during the project (in the project statement, during the meeting with the tutor, etc.), the project objectives must be kept in mind: to acquire new knowledge and competencies, and not merely to demonstrate an ability to apply previously acquired capabilities. This is particularly true during the project assessment. The assessment should focus on the learning and not only on the result.

In our programme the final assessment is carried out by a jury composed of three or four people, each one is competent in one discipline connected to the project (physics, computer science, design). Sometimes an expert from industry is added to the jury. The examination consist of two sections.

- *Project group assessment* (typically 30 min). The students present their project; members of the jury ask questions on the project, the process, and so on. Sometimes we also give questions in advance and ask a particular student to present the answer. We do not intend to evaluate the student who answers, only the way the group has prepared the answer. This should motivate the discussion and exchange of knowledge among the students of the group. At the end of this section, the jury awards a group grade. This assessment takes into account the report and the teamwork.

- *Individual disciplinary assessment* (typically 1 h). The jury puts disciplinary questions to each student individually. The objective of this section is to evaluate the individual knowledge of the student. Once again it makes clear that the objective of the project is not the solution, but the learning.

Main characteristics. The main characteristics of a pre-project may be stated as follows.

1. The statement clearly indicates that the objectives of the project are the solution and learning of new concepts and methods, the 'solution' is not the objective, but only one way to assess that the objectives are reached.
2. From the very beginning and at any time during the project, the tutor and students must remember that the project is learning oriented.
3. The project is built by a multidisciplinary team of professors and is integrated into the semester objectives.

4. Conclusion

In our new curriculum, we implement an original connection between a project and a short-term problem, and call it P^2BL. Problems are used mostly within a single discipline and over a shorter time span, allowing our students to delve in a more controlled way into disciplinary topics than to projects. Projects are long-term interdisciplinary activities. We have an extensive experience of projects in our faculty, but when we had to prepare the first project we faced a major problem in defining its objectives. It appears that classical synthesis and a result-oriented project (called post-project) was not applicable to our new programme. As a consequence, we had to develop a new type of project called a pre-project. To put it in a nutshell, a pre-project is a learning-oriented project, meaning that the result is the solution and the acquisition of the learning objectives. Such projects come before (or simultaneously with) the courses and are used to contextualize the concept. The two types of project have different objectives, characteristics, assessment and tutoring principles. They therefore have different but complementary domains of application. The pre-project may best find its place of application in the first year of an engineering curriculum.

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