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LARGE TEAM PROJECTS – AN ALTERNATIVE TYPE OF MASTER PROJECT?

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ABSTRACT
Whereas our study program has been fundamentally revised over the last 10 to 15 years, the master project is very much as it always has been: A project more aimed at showing what has been learned during the preceding study than at learning. This is at odds with the steadily increasing demands from industry for candidates that can go directly into productive work after they are hired. In an effort to increase the learning and "produce" candidates better suited to industrial demands, we have developed a new kind of master project as an experiment. In this, a large, multi-curricular team of students do a realistic project from start to finish. The focus is on realistic problem solving, on cross-disciplinary learning, on working within fixed deadlines and on getting the necessary resources for the project. To a certain degree evaluation is sacrificed for learning. The first results are in, and we need to evaluate them and find out if this is a type of master project we would like to see more widespread use of.

Keywords: Project based learning, cross-disciplinary teams, learning content

1 INTRODUCTION
Most industrial companies experience an ever increasing pressure to lower cost and faster delivery [1]. This means that in-company training becomes less and less desirable; they want to hire candidates that deliver results as fast as possible. Universities typically focus on learning scientific basics for engineering, and expect the companies to do the education needed for the specific job afterwards. But now, universities are challenged to "deliver" students that perform after very short time. For design students, this means to perform productively in a product development project after very short time. It means knowing how to perform in an integrated, cross-disciplinary and systematic project.

Like many others, our design education has a master project during the last year. Typically, the candidate is given a problem to solve, and he works alone on this. Teachers see it as an extended exam: The student uses the project to show what he has learned during the preceding study. One result of this is that many students have limited learning results from the last year of the education.

In order to make the education better adapted to the reality that will meet students in industry, we need to expand learning to include work methodologies and team work, and make the students able to handle a typical industrial design situation, where information is sketchy, decisions must be made based on limited information, and where available time and resources do not seem to be adequate.

This paper reports on an effort done at The Norwegian University of Science and Technology to improve the master project. It started in the Mechanical engineering program, but was expanded to go beyond that. The preparation for this effort started in spring 2007, the actual project started in fall 2007, and the paper is based on the status at the end of the spring term 2009, that is after two years.

2 APPROACH
We wanted to improve our master study by making our students more adapted to the industrial reality and more able to cope with the conditions offered them in industry. We therefore decided that we would try to do something more out of the master project.

2.1 Increased learning
Using almost a year of the study only to evaluate the student, seems excessive. There is no indication that employers would prefer a precise ranking of students over a general expansion of their knowledge and capabilities. We therefore decided that learning should be the focus more than evaluation.

If we focus on making the master project a learning experience, we may have to compromise when it comes to evaluation and grading [2].

2.2 Realistic challenge

A major problem with typical master projects is that they are simplified. This means that the student get a type of problem which is adapted to what he has learned, and where all “disturbing” elements are removed. This is very different from what he or she will later experience in their work life. In typical design situations, finding out what the essence of the problem is, is often a major part of the work. So we wanted to give students a realistic challenge, where they themselves would have to find out what technologies to apply and what solutions to investigate [2].

2.3 Measureable goal

Designers are not often given tasks with simple answers. The answer should be a successful design. We therefore wanted a project where not reaching the goal was not acceptable. Students have a tendency to reduce the challenge by saying that “I didn’t reach the goal, but at least I have shown that I know how to work in such projects”, and this we would not have here [3].

2.4 Cross-disciplinary team

If anything characterizes modern design projects, it’s the cross-functional project team. All products are cross-functional to some extent and many more and more so. The “lone genius”, who sits by himself and solves problems within his specialty, is not a common sight.

Cross-disciplinary means that different engineering as well as non-engineering disciplines like marketing, finance and psychology have to learn how to communicate and cooperate. And integration of disciplines is a challenge, since terminology and scientific traditions are very different [3].

2.5 Resources

Any realistic project requires lots of resources. Usually, they are not readily available, and must be found. Economy is one such resource, and in our case, university funding is minimal, so the project needs sponsors. Finding good sponsors, making the right contract with them, and making sure they are satisfied with the return on their investment is a vital part of such a project.

There is no technical aspect of this, but still it is very close to the reality that the students will meet in their work after their studies are over. Designers in industry must always sell their ideas to those who control the resources – management, financial resources, etc.

Other resources (scientific competence, materials and workshop facilities) were more or less available.

2.6 Teacher’s role

Whereas in an ordinary one-student-one-teacher project the teacher will be the student’s main discussion partner, this will not be the role here. Much more, he will supervise the project’s progress and facilitate student activities [4]. For the students, the most important discussion partners will be the other team members. Since these are from different science areas, they may be able to answer many more questions that the teacher can. The teacher’s role will be to watch over the project progress, and to guide the team in the right direction.

If students from multiple departments are involved, a teacher from each of the departments should also be involved. A benefit of this is a “teacher team” that would represent very diverse competence and knowledge, and which could be interesting as discussion partners also between themselves.

3 CASE STUDY – EXPERIMENT CONDUCTED

3.1 Choosing a project

One of the product areas focused by our department is transportation products. Here we find some interesting competitions for student groups. Foremost among these, are Shell Eco-marathon, Formula Student and Formula Zero, Figure 1, plus some solar energy vehicle competitions.

Figure 1. Formula Zero, Shell Eco-marathon and Formula Student

For us, one stood out: the Shell Eco-marathon. This is a well-established competition with environmental focus and with participation from the most respected universities in Europe and beyond. Shell Eco-marathon is based on a simple idea: Student groups should design, build and race a car with fuel economy in focus, within specifications set up by Shell. The success criterion is how far it drives on the energy equivalent of 1 litre of gasoline.
Each car is given three chances to race, and the best result counts. To get a result, the car must finish a distance of 23km with a minimum average speed of 25 km/h, and with 3 required stops.

3.2 Establishing the team

We are not in a position to pick “the best” students. Basically, the students can choose for themselves from a catalogue of project possibilities, and as long as the number of applicants corresponds to the number of openings, we accept them. It was easy to fill the mechanical engineering student positions, but it was more challenging to find students from the other engineering fields. This might be because such a project will have to be evaluated differently from traditional projects, and potential students might not have gotten reassurance that their professors would indeed do this [5, 3].
The mechanical engineering students represented a good cross-section of the student mass, both in interests and in scientific achievements. They were not an elite, which is important since we will see if this type of project can be used much wider than in only one project.
Eventually we found students to cover our needs in the project. We ended up with students from power electronics, fluid dynamics, industrial design and project management. In the second year we also included a chemistry student and two from cybernetics.

3.3 Getting the resources

Some resources were readily available, some were not. In the first category we have a nice workshop with machines and general tools. In the second was funds.
The first student group made a budget of roughly 120.000€. The university had only about 800€ per student, so more than 90% had to be found from other sources. Finding sponsors were therefore critical: We would have to find business sponsors who would like to have their name associated with our project. As it turned out, a major hotel chain, which is very high profile in environmental issues, wanted to support us and gave us the amount we needed. Smaller sponsors were also found, mostly providing materials or services rather than cash support.

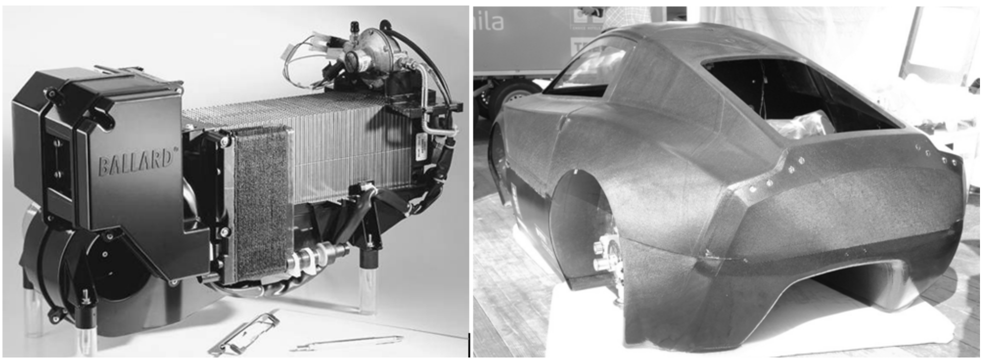

Figure 2a). Fuel cell b). Carbon fiber monocoque

As our department is very competent in both lightweight metals and polymer/composite materials, the materials issue was costly but not difficult. To get an edge on the competition, we decided to go for a carbon fibre monocoque (see figure 2b) – the competition all had frame based designs. This meant expensive prepreg carbon fibre and a high quality moulding process and a high quality form. It had probably not been feasible had we not found a partner – a sponsor – who let us manufacture the mould at their premises, let us use their autoclave and provided valuable assistance in the whole process.

Many of the components were small and could be bought off the shelf, but two important components were in a different league: The fuel cell and the electromotor. In the first year, we had too little knowledge to try to build anything ourselves, so we ended up with the same off-the-shelf fuel cell solution that our main competitors used (figure 2a). And we chose a model airplane electromotor. In the second year, we had a chemistry student and a cybernetics student to work on the fuel cell, and a power electronics student with expertise on motors to work on the motor. We therefore chose to purchase just a fuel cell stack, and build our own system out of it, and to design our own slow-revving electromotor. Both of these components were major contributors to our success in the race.

3.4 Developing the solutions

One of the decisive factors of such a project is the sheer number of engineering challenges. A car is an extremely complex system of parts, organs and solutions, and all of these need to be solved in order to have a potential winner. It might seem like a good strategy to subdivide the system of the car into a large number of parts, and then start work on each of these separately. In that way, work could be divided between team members easily. As designers, however, we know that not only will this not be optimal, it is usually not possible. A systems approach must be taken [6].

As an example of the systems approach, our team started out with a discussion on the general structure of the car. Almost all competitors used a frame structure, but we decided to go for a monocoque structure, in which the body forms a shell which is the carrying part of the structure. We can easily see that this decision was important for those developing the body – influencing even the shape of the body. Maybe less obvious, this was also decisive for the development of the wheel suspension and the propulsion system. Almost everything was influenced by this decision. This is just how the theory of technical systems describes it. So, although the project had to be subdivided between the students, a large part of the decisions were at systems level and needed to be made across these subdivisions.

In the propulsion part of the car, we find that the decision to base it on a fuel cell and electromotor, had far-reaching consequences also for those working on suspension and body. And even the propulsion is a cross-functional effort, were we had chemistry majors working on the fuel cell, electro majors working on the electromotor, mechanical majors working on the transmission to the wheel(s), and cybernetics majors working on the control logic for the fuel cell-electromotor combination. No decision could be made on a fuel cell configuration without regard to the electromotor, and vice versa.

Industrial design students are trained to think of users, functions and aesthetics. In our case, however, aerodynamics was a big issue. Aerodynamics is only connected to 3 features of the car: shape, dimensions and surface quality. Of these, shape and dimensions are features that have strong bearing on almost everything else in the car, and cannot be decided upon for aerodynamic reasons alone. We therefore needed the aerodynamics major to work with the industrial design majors to find a shape and dimensions that satisfied all other requirements as well.

3.5 Supervision

Supervising projects is a major part of the work when you have as many as 5-6 students every semester. In fact, it is a limiting factor, as a larger number of students could often be desirable, but would require more time than is available for supervision.

The experience with the large, cross-functional project is that it reduces the supervision effort. The students support each other, often solving problems without even involving or informing the supervisor, problems that would otherwise mean work.

3.6 The issue of grading

The issue of grading has been a difficult one. We soon decided on common grades for the team, since it would be very difficult to identify individual results in such a project, and because if each should be evaluated on his scientific contribution, nobody would do the tedious, but necessary, sponsor work and press relations work. Since the final project counts more than other courses, many students are sceptical to being dependent on others' effort and performance for this grade. Some feel that they can do better on their own. This is an issue when it comes to recruiting students to the team.

In our tradition, the grade is based on the report from the project. There is no grading at intermediate stages, but the teacher could include an evaluation of how the student has worked. We also bring in an external sensor to set the grade together with the teacher, but only after the project is finished.

Grading based on report alone, would in this case be impossible. If we said from the start that the project would be graded based on the report, the project would be in jeopardy, because so many crucial elements would be ignored. Although the report was still important, we had to include many other issues in the evaluation.

4 RESULTS

4.1 Academic results

Academic results from the project are not easy to pinpoint. Each student had his/her own results, but the main academic result is that each student has seen his own knowledge and competence go into a practical project, and has seen that without the knowledge and competence of each single one of them, there would not be a result like the one they achieved [7]. Another effect, which is important but often overlooked in universities, is the learning across curricular boundaries that happened in the project [7]. For the first time, we saw cybernetics students interested to learn more about engineering design methodology, electromotor experts working with mechanics students to dimension parts of the motor properly, and mechanical students with a whole new understanding of cybernetics, etc, etc. This is the second important academic result from the project.

4.2 Project results

Finding sufficient funding is critical in a large project. Materials, components, resources all depend on funding. Our first year team ended up with a very good deal with a hotel chain, whose owner is known for his dedication to all things green, and also for his car interest. The second year we found an even better sponsor, a company which, among other things, does ISO9000 and ISO14000 (environmental) certification. The company is a large employer of former students from our program, so it was interested both in the technical aspects of the car and in the learning in the project. They eventually hired the team leader.

The three most important components of the car are the body (weight, aerodynamics and stability), the electromotor (gearing or not; efficiency) and the fuel cell (efficiency of electricity generation).

The first year group emphasized the body, and found a sponsor with lots of expertise in carbon fibre fabrication, which also has excellent facilities for making both the moulds for such a large component and for making the actual body. The result was amazing: Whereas no competitor's car weighed less than 94kg, ours weighed 69! The other two critical components did not get the same attention, and were off-the-shelf products: A model airplane electromotor and a Ballard Nexa 1200 fuel cell.

The second year group early on decided to keep the car body as a basis for their development. They got it into the wind tunnel and found it less aerodynamically efficient than expected, and therefore sought ways to improve on the aerodynamics without ruining the good properties of the body. They ended up with three main alterations: The rear end was lengthened to get a more laminar air flow, the duct under the car was covered, and the mirrors were moved from outside the car to inside.

But the main focus was on the other two components. Instead of the off-the-shelf fuel cell, a Ballard stack was bought, and the team made the system themselves. This means that they designed the entire control system for the stack, including feeding, and also the cooling system. The result was found to be much more efficient electricity generation, and a system we had much more control over. The first year electromotor was a high-speed unit, and it required a 10:1 gearing in order to work in the car. A gearless solution based on a low-speed motor was identified as a potential source of improvement, and a sponsor was found with expertise on such motors. The students designed their own motor on the basis of the sponsor's technology. The result was a motor which did not require gearing, and although much bigger and heavier, a much better solution.

We had told the students that starting in the race was a demand, and that anything but a valid result would be considered a disappointment. This was contrary to some observers who said that "whether they finish the car or not, they have learned a lot and can write a good report". In an industrial project, you are seldom recommended for having tried, you must finish, and we wanted the students to experience that kind of pressure.

The first year, two of three heats were successful, and yielded a counting result of 729km/l. This gave us the silver medal, behind a Dutch team that had won for 4 consecutive years.

The second year, we had higher ambitions: the goal was 1000. With the new motor, the new fuel cell, the improved aerodynamics and all the new computer support being available to the driver, beating last year's result was expected. This time we did not finish the two first races, but then we were successful. 1246km/l was a new record and 50% better than the silver medal winner!

4.3 Team results

Both teams were given a task which they thought was beyond their competence. They had never before experienced such a serious project, with such high demands, so large and diverse a team, and no tasks defined, only goals.

The first year team reached their goals and they were good at involving the supervisor group and the sponsors. Documentation was somewhat haphazard; the team obviously did not see the value of good, structured files, and they relied heavily on the collective memory of the team. And that worked well for them, but made things more difficult for the team taking over after them. Their effort on the PR side was recommendable: They appeared in newspapers as well as radio and TV. Norway's leading TV channel followed the project from the onset, and even sent a team to cover the race in France. What resulted was a long feature on the most popular TV news show on the most popular hour of the week. This was excellent PR for our university and our education program.

The second year team organized themselves differently. They were very good at subdividing the project into manageable tasks for each student to fulfil, they used their allocated project area to good effect, and had a less formalized work style. This meant less involvement of both the supervisor group and sponsors. Report writing was a one-man effort by the team manager. The resulting reports were neither very well written nor going into sufficient depth on the most critical issues. All in all, reporting was probably the team's biggest shortcoming.

5 CONCLUSIONS

The results so far are promising. Our expectations have been more than fulfilled.

The students participating in the two groups report a level of learning that far surpasses any previous 5th year results, and in fact also the preceding years of study. We have also seen that the learning has been achieved in exactly the areas that industry needs the most, practical project work and cross-disciplinary integration.

The next challenge is to expand this to other product areas. We have not yet concluded on which, as especially the availability of potential sponsors is critical.

Evaluation is the Achilles heel of such projects, and needs further development.

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