GUIDELINES FOR COOPERATION BETWEEN INDUSTRY AND ACADEMIA IN DESIGN PROJECTS

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ABSTRACT
The cooperation between firms and academia is often seen as an effective way to provide disciplinary skills and knowledge of system building for inexperienced students. In theory, cooperation has many advantages: The students get first-hand knowledge of the industrial environment and experiences of working with professional designers. In this way they get an opportunity to feel the pace of realistic projects as well as an opportunity to show their skills for future employment. Not only the students benefit from this cooperation; the firms gain new innovative ideas and knowledge of the latest development techniques. They also get good leverage on the resources invested since the amount of hours spent by the student teams could be tenfold the contribution of the firms.

In real life, the cooperation between firms and academia can be both time-consuming as well as troublesome. One reason for this is that their objectives are different: The teachers want the students to learn and the companies want to make money. To overcome unnecessary barriers in cooperative design projects, a set of guidelines have been created at the School of Engineering at Jönköping University in Sweden. The guidelines have been developed from the experiences of collaborating with more than 30 different companies between the years 2000 to 2006. One finding is the importance of aligning the expected project outcome between students, teachers and companies. Another important aspect is to ensure that the standard of the work is high enough in order to satisfy the firms. This is achieved by a careful selection of projects and by comprehensive coaching of the students using a proven framework for learning design.

KEYWORDS
Industrial cooperation, design projects, guidelines.

INTRODUCTION
Before any implementation of a cooperative design-build-test (c-DBT) experience the first step is to consider the reasons for starting the cooperation. Is the reason that it is beneficial for the students and a true improvement of the learning environment? Or is it just a matter of making the program look more attractive to students and other University stakeholders by offering some variation to the standard coursework?

Compared to traditional classes, a DBT experience usually needs significantly more resources [1]. In our experience, a collaborative DBT project is no exception but rather more expensive and complicated, especially since the outcome is hard to predict in advance. Other reasons are the costs for material and travel, the time spent on finding projects and the need to ensure that the rules for examination can be fulfilled. On top of this there are usually

discussions on intellectual property rights that can result in legal consequences if they are not properly solved. These questions must be solved for every participating company.

In spite of the troubles to set up the cooperation, it is usually well worth it for all participants. Through course evaluations we know that the students are positive to the experience of collaboration with companies, even when the technical output of the projects did not meet its goals. In almost all cases, the firms too were satisfied with the cooperation, which is foremost displayed in the requests for new projects. The aim of this paper is to share our experiences and to offer guidelines for setting up and maintaining carefully managed design-build-test projects in cooperation with the industry.

The CDIO perspective

A cooperative design-build-test project fulfills at least three CDIO standards [2]. Students developing a product by involvement of industrial partners correspond to standard 7: Integrated Learning Experiences. The physical output of the project is a model or prototype built from the information created by the students such as drawings or CAD- models. Usually students make most parts themselves in our workshop, some parts are manufactured by the participating company and other parts are printed in our 3D printer. This corresponds to standards 5: Design-Build Experiences and 6: CDIO Workspaces.

The learning context

To understand the context of the c-DBT projects at the Department of Mechanical Engineering, a short description of the education structure is given. In the Bachelor program a plan for design-build-test projects is used which includes a systematically varied sequence of DBT- experiences across the latter half of the program. When students are to learn practical engineering by designing and building a physical object it is important to avoid that the design work becomes an ineffective happening. Therefore a framework for design projects is used to provide a clear structure and a context where students can practice their engineering skills and knowledge from previous courses.

The first 1.5 years of the program consists of a traditional setting with individual studies of basic subjects such as manufacturing technology, material technology, mathematics and physics. The following year is quite different with design courses in collaborating groups. The last six months consists again of mostly individual work. The first significant project starts at the end of the second year and is a cooperation between courses in industrial and engineering design, emphasizing creativity and skills of team work. This is a ten week full time assignment capturing the design intent from idea to CAD drawings and model/prototype manufacturing. A comprehensive description of the framework used for design projects can be found in [3].

The second project is the subject of this paper. It is a cooperative DBT experience between the School of Engineering and companies in the surrounding area. Compared to traditional capstone- or thesis work, it is a much quicker, more carefully managed and less extensive assignment where the project part accounts for 4 ECTS. The teams consist of 4-6 students applying their skills in teamwork, design and project planning/execution gained in the first project. The goal is to acquire disciplinary skills by designing something useful for a demanding customer. The lectures in this course focuses on methods such as QFD, selection procedures, Design for Manufacturing and other practical tasks that are directly applicable to the project.

The third project is the 15 ECTS Bachelor thesis work which is usually carried out by two students together at a suitable company. The thesis is the largest and most important work in the program, showing to what extent students are able to apply and add to knowledge gained during previous studies. During the thesis work, students are judged on their ability to identify and analyze problems. They are expected to describe the method of work and how the

solutions fit into the context of the assignment. The thesis comprises a theoretical approach to the subject and a clear presence of analytical and developmental work.

PLANNING FOR A DESIGN-BUILD-TEST COOPERATION

Cooperation between industry and academia is common practice in Sweden and has been going on for decades. Most engineering students do their final project in cooperation with a company and up to recently they also had to do at least two months of internship before receiving their exams. In our case we wanted to offer another type of experience managed in a similar way as industrial projects. The role of the project groups resembles design consultants working in a controlled environment on a well defined task. The support and guidance from teachers and the advisor on the company gives the students an opportunity to participate in the rapid pace of realistic projects exercising their skills form engineering subjects.

In order to create a base for the projects basic questions must be asked:

1. What do we want the students to learn from the companies?
2. What do the companies want from the students?
3. What will the teachers gain from the cooperation?

The first year of collaborative projects were run without these questions explicitly answered. The main reason for cooperation was to increase the “fun factor” in the course and also to add some realistic pressure by bringing in external stakeholders in the process. The effort however was repaid when one company used the students design as a model for a new product. This showed that the students’ skills were good enough to create a commercial product and encouraged the set up of coming collaborative projects.

What do we want the students to learn from the companies?

The main reason to include externals stakeholders in education is that they offer competence and experiences that is seldom available in the academic system. Therefore the most important learning outcome of the projects must be a transfer of disciplinary knowledge between the professional designers and students. In our projects, the transfer is mainly done through meetings where students’ designs are revived at different stages in the process.

The consequences of the statement above set the context for when industry cooperation is valuable to the students and when the costs exceed the benefits. It is not effective if knowledge available among the teachers is taught by industry and therefore mainly creative tasks where the result is of the type “concept development” should be avoided. The methods of innovation and creativity are usually well represented on universities and in our case the students acquire this type of skills in earlier courses.

What do the companies want from the students?

There are various reasons for engaging in student projects but one similarity is that educating students is not a part of their business plan. Our participating companies often mention reasons of goodwill and marketing as well as the opportunity to get new ideas and to explore low-priority technical solutions. The goodwill often consists of the opportunity to attract future employees and customers and is often mentioned by firms with less attractive products and locations.

The companies usually do not intend to use the project results immediately but are instead interested in the new opportunities that may arise when young people treat concrete problems in different ways than their experienced designers. Therefore companies are often interested in “concept development” which is ineffective in transferring disciplinary knowledge as discussed above. Another point of interest for the companies is to get help with labor

intense research processes, such as finding new information through searches in patent databases or market analysis. This type of analysis is usually of mutual interest of students and firms, since the students are given input to the design process in the form of product knowledge and alternative ways to solve its functions and the firms are given valuable information.

What will the teachers gain from the cooperation?
The benefits for the teacher's are not easy to pinpoint. Clearly there must be some incentives in order to make the teachers committed to the work, especially if the c-DBT project is promoted and initiate by the academic management. In our projects we have found that the teachers gain new knowledge and make new contacts in a pleasant way.

EXPERIENCES OF COOPERATIVE DBT PROJECTS

Our view of cooperation with firms in carefully managed projects has gradually evolved through guided projects on more than 30 different companies. After seven years of different set-up of c-DBT projects we have created guidelines that have proven valuable in the process of reaching the different goals set by the students, academia and companies. The type and size of the company can influence the results and we have cooperated with small companies, large companies as well as individual inventors and public service institutions.
The size of the groups has varied between three and six students per project. One year all groups worked for a single company, another year there were ten groups working for ten companies.

Descriptions of the c-DBT projects
The groups of students act like a consulting firm integrating the industrial design and engineering processes in a controlled project environment. The purpose of a well defined assignment and the controlled process is to speed up the work so that the whole design chain can be run through before the end of the course.

The companies are not required to coach the students in their designing; their role is to act as project sponsors and supervise the work. The students need a company contact and advisor that has enough time and knowledge to give professional feedback. The framework guides inexperienced students through the process, and frequent hand-ins sets a steady pace and gives short feedback loops. It is also easy to monitor the progress for both teachers and companies when different tasks are handed in every week.

The assignments are coming from the companies and the technical goal of the project is to develop products according to specifications. The course provides lectures on different aspects of product design and the project is the arena to implement it. Most of the work is done on campus, but with frequent contact with the companies.

The set-up consists of three parts:

- The DBT- project framework
- A company contract/assignment
- The cooperation guidelines

Our DBT framework [3] is used as a cornerstone in our c-DBT projects and consists of a formal development and project execution model, training in group-dynamics by professionals and extensive coaching or the students. Before the framework had reached its current stage of development, the output of projects would be very variable. Some groups of students had a natural ability to fulfill both the goals of the course and of the companies while others could not fulfill any of them, and there were no effective mechanisms to catch and correct projects on the wrong track

The company contract/assignment is a document containing the project description and the preliminary technical specification. The specifications are usually flexible and are used as a base for development. The contract usually does not contain any information on intellectual properties rights. These rights control the ownership of potential inventions and are usually only discussed orally before the projects starts. The reason for this is that companies are reluctant to sign complicated contracts before any results are present. Neither are we willing to sign off the students´ rights to their own inventions. Whenever a project shows a patentable invention a contract can be negotiated.

The cooperation guidelines are used by the teachers to find and evaluate appropriate projects and companies. Their purpose is to help avoid unsuitable projects, assignments or companies.

Student skills required before participating in cooperative projects

In order to make the most of the opportunity of working with professional designers it is important that the students are well prepared. Besides a basic technical knowledge, they also need to have some knowledge of their technical discipline and of practical teamwork according to figure 1. To make the project execution run smoothly we have found that previous experiences of development projects is very valuable for the students to focus on the work at hand rather than how the work should be done.

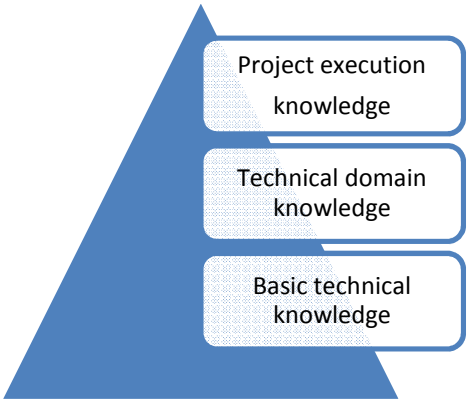

Figure 1. Skills needed in cooperative projects.

Finding the projects and companies

Finding appropriate projects includes more than just finding the cooperating companies: Bear in mind that the object is to expose the students for professional designers and their working practices, not to produce drawings or prototypes. We recommend working only with firms and individuals owning sufficient knowledge in the engineering domain. Knowledge in management or marketing cannot help students gain disciplinary skills. All types of companies offer unique project characteristics that need to be considered: The size of a firm influences the maturity of formal development and other processes and the type of business influences the speed of technology change. Some organizations spend 2% of turnover on development while others spend 20%.

In most DBT-projects the assignment is crucial. The students spends most of their time working on the project rather than reading course literature so careful planning is needed in order to create a satisfactory project. However, in c-DBT projects it is not possible to adapt the assignment perfectly to the course requirements and therefore the search and selection of projects is very important.

The assignment must fulfill the following requirements:

- Appropriate size
- Correct project type
- Suitable time frame

Fulfilling two out of three requirements will not be enough: A too large assignment will not be able to finish on time, an incorrect project character will not give an effective learning learning and a bad timing is not attractive to the company or school.

It may seem impossible to set up suitable projects, but the good news is that the firms are usually interested in compromising and the assignment can be twisted so suit the course. If the assignment is too small the teacher can add tasks, if it is too big, individual tasks can usually be divided among different groups of students. If the time frame is unsuitable the project could be saved for next year. If the project type has a wrong character, for example mostly "concept development", tasks can be reduced so that other parts of development also can be implemented.

A search for appropriate projects is often time consuming but also a good excuse to leave the office. In our experience suitable projects usually can be found through the personal contacts of academic staff, alumni networks and in favorable companies such as donors. If the project yields good results, the companies are usually interested in hosting projects the coming years. It is a good idea to cooperate with one company for two consecutive years, after this their most suitable projects are already used and they usually need to rest in order to have new proposals.

The re-design projects

One class of design projects that usually fulfills all requirements is the improvement of an existing product. A re-design activity is also the most common task in industry which prepares the students for a future engineering career, and there are usually many potential re-design projects in a company. Although it may seem as if the re-design is less creative than an explorative project, the potential different solutions to the task are still almost infinite. One positive effect of the constrained design options is that it hinders any lengthy searches for alternative product types and quickly leads to result. In this type of project the goal is to learn industrial procedures for creating, calculating, selecting, modeling and documenting products. In the case of re-design there is a lot of available data and documents that can serve as a guide for learning design work.

Arguments for cooperation

Even though the companies do not expect to get an ideal output, they expect reasonable results and there are at least two arguments to convince them that the projects will be worth the time spent and that the quality is good enough:

- Good leverage on time invested
- Commitment from the teachers

When a group of five students are spending a total of 500 hours effectively on the project they will make significant contribution if they are managed in the right direction. To further ensure that the standard of the work is high enough we always assigns two separate groups to the same project and so far at least one group in every case have created a satisfactory solution. Having two groups increases the competition without increasing the workload on the company too much and it is a suitable compromise between redundancy and time spent.

The teachers commit to invest time in comprehensive coaching of the students, provided that the firms also will take an active role in the projects spending an average of 15 to 30 hours

per assignment. The technical output of the project is depending on the guidance of the firms and the teachers cannot replace the knowledge of the professional engineers.

Alignment of goals

The adequate quality of design work is found by the alignment of the expected project outcome between students, teachers and companies. An alignment of the visions is crucial since the objectives of the participants are very different: The teachers want the students to learn and the companies want to make money. A first alignment is the preliminary specification that sets the context for the project. Other alignments are done through the project checkpoints. Students share their initial ideas, get feedback from teachers and firms and continue to refine the most promising ones. The company participates in important steps such as concept selection and shares disciplinary knowledge by comments and suggestions. One important role for the teacher is to assure that the project scope does not expand and stop any additional assignments unless the basic requirements are not fulfilled.

Common problem in cooperative projects

During the years we have encountered a variety of problems and the most common ones are listed in Table 1. In this table is also a brief description of the countermeasures that we used to minimize them.

Table 1
Common problems in collaborative projects

Problem	**Primary cause**	**Effect**	**Countermeasure**
Time delay	Students have not enough experience of development	Not reaching learning goals, not delivering results	Academic design project before collaborative project ensures first-hand experiences of product design projects
Time delay	Project too extensive	Not reaching learning goals, not delivering results	Ensure proper project size before project start.
Project breakdown	Students have to little skills in teamwork	Poor overall result	Acquire teamwork skills before collaborative project
Project not reaching company goals	Changing specification during project	Company not satisfied	Teacher intervention- ensure that project scope is not increasing or significantly changed
Project not reaching company goals	Too little company commitment	Company and students not satisfied	Make sure that company has enough resources before project starts
Project not reaching company goals	Project result not up to expectations	Company not interested in future cooperation	Redundant projects- at least two groups working on the same project
Students not reaching learning goals	Too high project workload	Teachers not satisfied	Teacher intervention- ensure that projects do not overtake other learning activities.
Students not reaching learning goals	Unsuitable project character	Teachers not satisfied	Ensure suitable project character before project start.
Company or students not satisfied	Disagreement over intellectual property rights		IPR contract is negotiated before project ends

The countermeasures include activities before the c-DBT project or direct teacher interventions and this stresses the importance of having enough resources to coach the students in their work. All of the problems are addressed in our guidelines.

Guidelines for cooperative DBT projects
Our experiences can be summarized in the following prescriptive guidelines for controlled cooperative DBT projects:

- Use a proven framework for design projects
- Students should have at least one similar experience before working in a company project
- Students should have basic knowledge and personal experiences of group dynamics.
- Two student groups per project enables redundancy without giving the company to much extra work
- Cooperate with competent companies and avoid inventors or organizations without disciplinary knowledge
- Use the company competence that is not available in the academic system
- Avoid cooperation in mainly creative projects since it is not an effective use of the company knowledge
- Search for re-design assignments to speed up project progress and use as a template for disciplinary knowledge.
- Don´t accept unsuitable projects
- Continuously align the project goals between students, firms and teachers
- Balance the need to learn and the pursuit of results
- Ensure that the company has resources available for the students and avoid too many groups on a single company
- Ensure that the teachers are given enough time for proper coaching
- Create a strategy for handling issues with intellectual properties rights

Comparison to an earlier study
A Comparison between the guidelines for c-DBT projects and an earlier study [4] shows a high correspondence between the findings, suggesting that the guidelines are suitable also for capstone design projects:

- *"The scope of the project must be appropriate…"*
- *"projects that are investigative rather than design oriented should be vetted by the course coordinator…"*
- *"Project scope should include a clear list of expected outcomes…the more detail included in the problem definition, the higher the likelihood of success for the project…"*
- *"The way in which the team of students works together will play a large role in the success of the project…"*
- *"Support and guidance from the industry advisor is critical throughout the project…A clear understanding of the course objectives…. by the industry advisor is also needed."*
- *"The academic supervisors involved in the projects must take an active role…"*
- *"Only through regular interaction between everyone involved will projects come to a successful conclusion…"*

CONCLUSIONS
There is no secret formula for a successful implementation of a cooperative design-build-test experience. We have however created guidelines that are relevant in our context of projects managed in a similar way as industrial projects. The guidelines also correspond to advice given in other studies. One factor of success is a careful selection of projects and a comprehensive coaching of the students using a proven framework for learning design. This ensures that the standard of work is high enough to satisfy the firms. Another factor is the continuous alignment the expected project outcome between students, teachers and companies.

REFERENCES

[1] Malmqvist, J., et. al., “Lessons Learned from Design-Build Test-Based Project Courses.” Proceedings of the International Design Conference, 2004.

[2] http://cdio.org/tools/cdio_standards.html

[3] Raudberget, D. and Cannmo, P., ”Learning product development through a design-build-test project – why is coaching important?” Proceedings of the 4th International CDIO Conference, Gent, Belgium, 2008.

[4] Surgenor, B., Mechefske, C., Wyss, U. and Pelow, J., “Capstone Design - Experience with Industry Based Projects”, Proceedings of the 1st Annual CDIO Conference, Ontario, Canada, 2005.

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