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# A sustainable, industry-oriented Concept for an integrated Project in Bachelor and Master Education in Mechatronics

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**Abstract**
The paper describes the differences in the theoretical background, methods and steps during the project works and the differences between the bachelor and master projects in the field of mechatronics. Moreover, the application and the results of the projects are discussed, with emphasis on the link to actual engineering environments in the engineer's world outside the University. Furthermore, the different size of the groups, structures and substructures of the teams, as well as the according assistance of the lecturers are explained. Furthermore concrete examples are explained and discussed in this paper.

***Keywords:*** ***Sustainability, industry-oriented Education, Bachelor, Master, Mechatronic, Project, Project Management, Cocktail Mixing Device, Test Device for Bikes, Unmanned Ground Vehicle.***

## Introduction

During the last decades, there have been a lot of changes in the fields of product design and product realization, many of them being caused by the use of mechatronics instead of classical mechanical engineering. Thus, universities have to adapt their education to the new requirements arising from changed industrial needs. This means, that lectures have to be supplied by laboratory work and project work. While laboratory work is a classical way to deepen and specialize a student's knowledge, project work is a way to broaden the knowledge, by integrating different disciplines but as well deepening and extending it, when necessary.

For these reasons, the faculty of mechatronics started with project work as a part of the education 10 years ago, trying to combine the knowledge of at least some lectures ([1, 2]). This was followed by its extension in an optional education module. When the faculty switched to the requirements according to the Bologna process, the change from diploma to bachelor and master degree took place. This was a good opportunity to re-design the whole educational concept of the curriculum (academic studies) and adjust it to the new industrial needs. Based on the state of the art ([3, 4, 5]), this was done and it was developed further on. Of course, up to now, the up to date developments are under consideration ([6, 7, 8]).

## Research Question

The question was on one hand, whether it is possible to develop a concept, which combines almost all fields of knowledge taught in lectures, showing the students benefits, use and interfaces between these fields. The knowledge should as well be deepened as enlarged.
On the other hand this education should follow the bachelor and master concept and should be close to the industrial need in the real life of an engineer. Management abilities should be trained during the project, too.
In order to improve the students' motivation – a prerequisite for optimizing the educational success – two goals have to be met by the project work's mission:

- the projects to work on have to be attractive and challenging to the students in order to create an initial motivation
- it has to be possible to fulfil the project requirements in order to avoid a loss of motivation during the project.

## Requirements and Concept of the Courses

First of all, the overall concept had to be defined.

So the situation has to be considered. The courses take place in the Bachelor and Master studies of the mechatronics education at the Department for Precision and Microengineering, Engineering Physics of the Munich University of Applied Sciences. According to the goal of the University, the education has to be scientific and should be close to the requirements of the later employment. So during the years in the University, the students have a lot of lectures, such as basic courses of mathematics and physics, up to the higher level courses of product design and design to cost. This is more or less the same situation in all good scientific Universities. But there is a need in this type of University, to educate closer to the real life requirements in their future working places. So students should have already some experience, which makes the time for introduction and training on the job as short as possible, to soon become employees, who are capable to do their job well.

Some years ago, there was the shift from diploma to Bachelor and Master degree in a lot of countries and in Germany too. So the change was taken, to make projects better adjusted to the later employment of the students. It was possible, as already explained, to use the knowledge of former experience of not compulsory projects, to optimize them and to enlarge them for the Bachelor and Master concept. Furthermore, the overall education system, consisting of Bachelors and Masters degree should be taken under account.

One requirement was, to create projects, which are linking already taught knowledge form former courses, such as product design and manufacturing (Table 1).

These contents should be improved and deepened. Of course, new knowledge has to be taught, which is related to the project, and/or to the future needs of the employees. So in the bachelor course, product design and manufacturing are being considered in the master course the lectures for design to cost and rapid prototyping have to be taken into account. Up to the project, of course there are small projects as well, but the target is only focused a single specific lecture. Herein, it is focused on different ones, where it is necessary to bring the different fields together. To get a more concrete feedback, compared with only paper work, the students have to prepare a task from the beginning up to the production and evaluation of a prototype. This gives students the best direct feedback. Up to now, the targets of the students from Bachelor and Master courses are more or less the same. The only difference is the quantity and complexity.

| Skills which should be transmitted | Bachelor Course | Master Course |
|---|---|---|
| Bringing knowledge from different courses together | ++ | ++ |
| Improving and deepening this knowledge | ++ | ++ |
| Getting new knowledge | ++ | ++ |
| Learning with direct feed back and optimize the use | ++ | ++ |
| Understanding, how to handle a product development process up to manufacturing | + | ++ |
| Handling different requirements and complexity (customers requirements, technical requirements, costs, etc.) | + | ++ |
| Understanding more about collaboration | ++ | ++ |
| Lean, how to manage projects | + | ++ |

+ = important, ++ = very important

**Table 1: Required transfered knowledge in Bachelor und Master courses**

If there is a look onto the understanding, how to handle a product development process up to manufacturing, there are big differences. The Bachelors project is of course not that complex and difficult, compared with the masters project. Furthermore the task itself is different. For the Bachelor course, the task ist quite concrete given by the lecturers. For the Master course students, it is necessary for them to work out, for example, the requirement more by themselves and to discuss and to confirm them with the customer. This needs an according size of the teams.

In most courses taking place before the described course, students have to deal with contents which are clearly restricted by the study course. But now, they have to take care about different opposite contents from different points of view. So they have to find their way, fulfilling most of the different requirements and collaboration with different persons and "departments".

## Team

One of the targets of the projects is, to work on complex tasks in teams

### Group and Team building

The students have to take care how to handle such different points of views in their groups. In Bachelors project, the teams are between 10 to 15 participants. This is even the first time, where they have to work in bigger teams. Up to this project, they are used to work in teams up to five members. So it is now more complex to handle the projects. That means, students have to divide the different tasks into smaller subprojects and according teams. Most groups are divided into two to four small groups which have to take care about specific tasks. This could be mechanical design, electrical design, programming, etc. Of course, the coordination between the small groups is, because of different points of interest, often not that easy and causes sometimes problems. But this is a similar situation as in later projects in the industry.

For the Master course project, it is much more complex. The total group size is up to 70 team members. That means, a good structure, fitting to the project and its tasks, is necessary. Students have to define the tasks and have to find a suitable structure for all group members. During some semesters, a project management team was installed, in some semesters, this task was taken over by the team leaders. The problem to handle 70 students, mainly by

students is a difficult task, but similar to a possible future team leader job in the industry. The lecturers are in this point only assisting and are, instead of the Bachelors project, normally not taking directly care about the coordination of the sub-teams.

**Motivation of the Participants**
The most important thing to make knowledge transfer to the students during the courses efficient, is to fill the students with enthusiasm. So there are tasks necessary, which inspire the students and on which they like to work on. This is a difficult task for the lecturers, because we don´t want to take a task twice and there are up to 3 projects, for example, in the Bachelors course in each semester necessary. Furthermore the tasks have to be related to the former lectures and the projects have to be sustainable. So the results should be used in further projects or should be used somewhere else for the University.

In addition, the lecturers have to be enthusiastic too. So the projects have to be diversified one hand and on the other, they have to be suitable to the knowledge and points of interests of the lecturers. The teams normally consist of three professors from the fields of product design, manufacturing/production and electronics/informatics. They are taking care about the tasks up to the assistance for the students during working on the project.

## Concrete Examples
To explain the above mentioned more in detail, concrete examples of the Bachelor and Master courses are explained.
One more common target is, that the projects have to be sustainable. That means, they have to be used for later projects or have to be developed further on.

**Bachelor Project**
Each Bachelor project runs one semester, because of the study plans. Furthermore, the projects should not be that complex and difficult for the students, because this is the first time, where they have to link the knowledge of so many study modules and have to manage a project by their own.

One of the first project was the development of a CNC lathe, which is used now to produce parts for the projects and was a base for learning more about realization. The project itself was, from the lecturer point of view, not that difficult. So they could focus more how to handle the whole process.

Then there was a shift to more complex one, such as a device for mixing drinks. This task of course, is quite interesting for the students, because it is closer related to their everyday life. Because of the group size, two teams, each approximately 12 persons where installed. To make more competition between the groups and avoid copying, they where given some restrictions. So one group had to mix the volumes of the liquid by controlling the volume and the flow has to be only through the gravity. The other group had to use pumps to control the volume.

Another restriction was the money the students got for the project. Of course, this budget makes it impossible to buy the complete device, but made it possible to buy the necessary components. For many students, this was the first time, they had a responsibility of `real`money in an engineering development project.

During each lesson, the structure is the same, more or less every meeting. First of all, the

students have to present the tasks they had have scheduled and what they have really done. After that, they have to present the targets for the next meeting one week later. Of course, students have to prepare at the beginning of the project task lists, schedule plans for financing, etc. Each student has to make one presentation per semester of his concrete task in the teams and what he or she really did.

This is one point for the final evaluation for the students. This bases 20% of the presentation and 80% of the project work. Each team member gets for the project the same evaluation, because we want to push the students to work together and get in experience in a team, where "only the results", similar to their job in the industry, count. So they have to solve first of all the problems in the team in the group. Of course, if bigger problems occur, the staff will be active to help the team during their job.

To work on the tasks should be self driven by the students, but the staff is assisting in all needed fields. These are to create the task, to work it out, to produce the products, to test and to evaluate it. Similar handled are subjects such as project management, including problem solving.

The process of the project is following. The lecturers give an introduction to the project in general, such as its purpose. Then general subjects are explained. These are how to define the groups. So the students have to define the teams themselves, only the maximum quantity and minimum skills of the members are given. These are, depending on the task, devided into smaller sub groups which have to fulfill different tasks according to the projects needs. Then the students have to take over the task for the project and have to define the users and to work it out. Beside, they have to define a schedule for the whole project, include financing. After that, they must fix the short term steps and they have to work them out, followed by weekly presentations and adjustment.

So during one semester, a device for mixing cocktails was worked and was finally presented by the students. This was evaluated by the lecturers. During the following semester, an ice crusher was developed, so there is a fully running device (Figure 1). This was already used several times, such conferences, the final celebration of the semester or start up meeting for a research project. Now, the unit is mainly used through the administration, which for example, uses the cocktail mixer as a reference project for attracting possible students to our study course of mechatronics.

**Figure 1: Cocktail mixing device during the use**

Concerning sustainability, the test device for bikes follows a little different target (Figure 2). During the first semester, more or less a standard test device was developed. During the second one, a shaker was included, to simulate a real street or track. Furthermore a possibility of adjusting the platform to slopes of plus/minus 16° was installed to simulate down or uphill biking. This semester this test device is used to develop concepts for energy harvesting during biking. This energy could be used for example to illuminate the bike or to load the battery for the drive. This test device is integrated into the bigger project of SUM (Smart Urban Mobility), which has the target to develop in a longer run concepts for urban mobility in general.

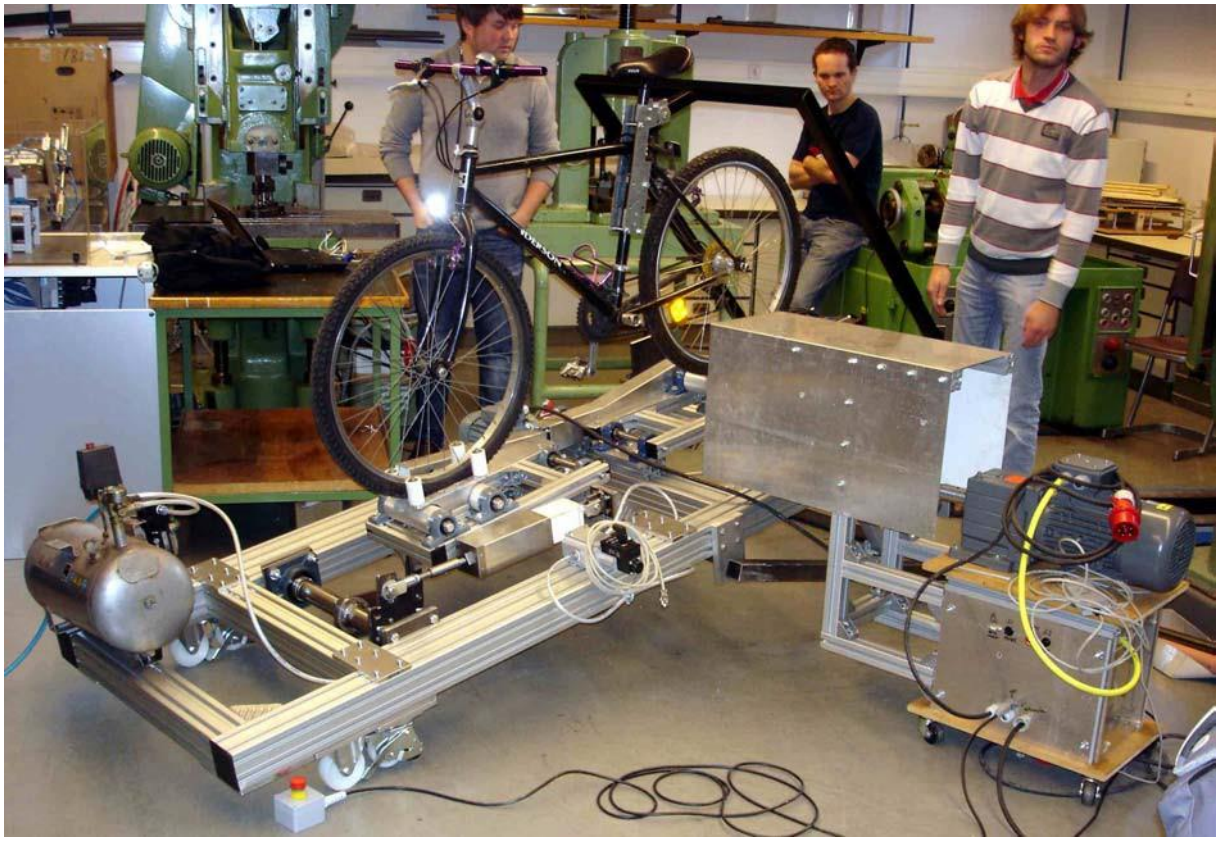

**Figure 2: Test device for bikes**

Because of the interesting project in total, the motivation of the students is very good. This makes the knowledge transfer to the students very easy and they are willing to work out new knowledge. Furthermore for the lecturers it is more interesting too, to have always diversified projects. So everybody is very hard working on this project. For the lecturers it is, of course, not that easy to find new interesting and for the purpose of education in mechatronic suitable tasks. But up to now the team of lecturers was successful.

**Master Project**

The master course, of course, has a higher level and further knowledge and skills should be created by the students. So there are differences between Bachelor and Master project.

First of all, the students have to work two semesters for the project. New students are integrated every semester, so there is always an overlap of the students. So the second semester students can transfer the knowledge to the first semester students.

Most students have passed our Bachelor study course of mechatronics. So they are already experienced to work on mechatronic projects in teams. That means, the Master project has to advance these students again with new aspects. The total team is up to 70 persons. Because of this size, the project management becomes now a more important subject. This big group is divided into smaller teams, which have sub project leaders. The data transfer of course is much more difficult now and close to the difficulties in their later job. Furthermore, the task should be more difficult.

The task is not given by the lecturers, so the students have to define the task according the customer needs. So the Bavarian police, the strategic innovation center is the customer in this project. The start-up was a given situation of hostage-taking, where students had to play the part of the criminal, the victim and the observer. According the experience and the following analyses, students had to define the tasks for a UGV (unmanned ground vehicle) and had to discuss it the with the police men. After this action, the students had to work out the concepts and had to build up the vehicle (Figure 3).

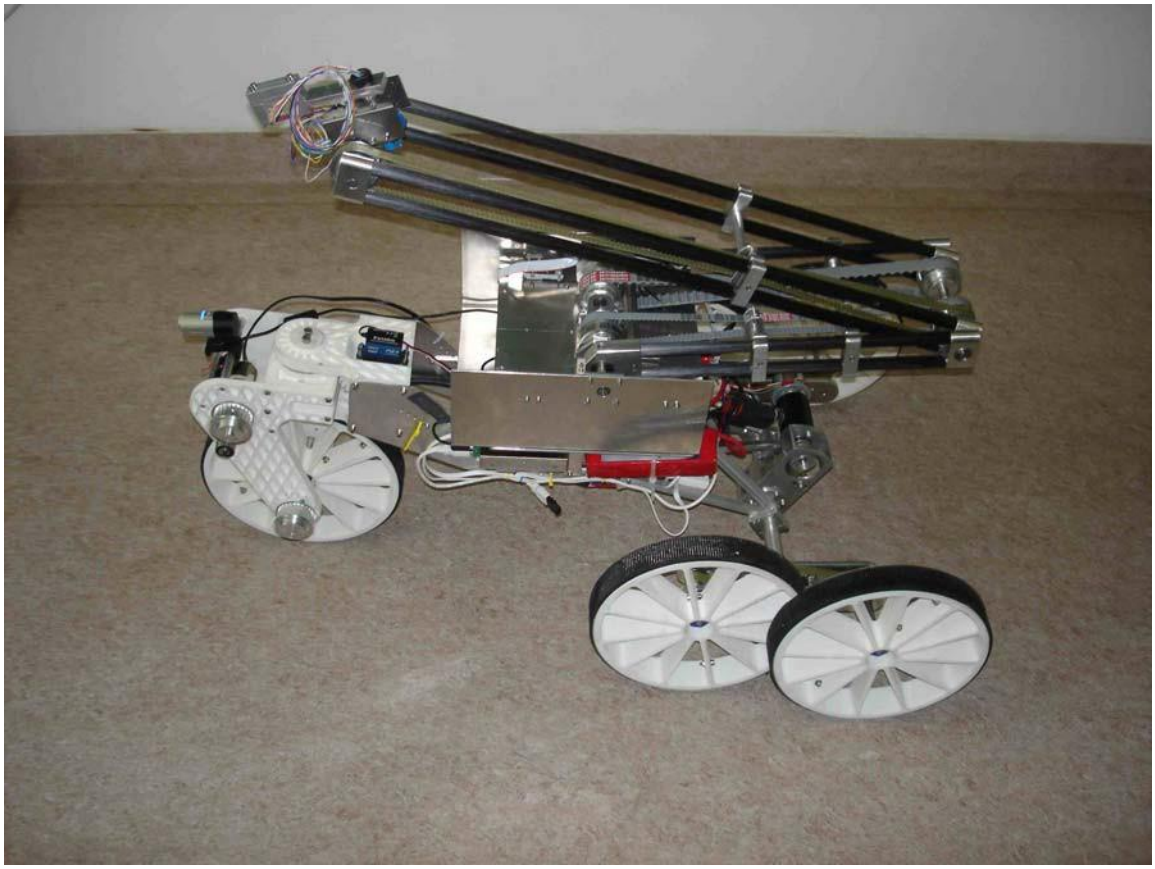

**Figure 3: Developed unmanned ground vehicle (UGV) in the master project**

To make this possible, of course, there is a founding necessary, too. In the Masters project, the students have to try to get money from the University. So the students have to try to get it for the tuition fee back for the project. To make this possible, they have to present the project and the scheduled budget for the semester to a committee, which distributes this money. If there is not enough money from the University, the students have to find sponsors for the project elsewhere. This is mainly from the industry and they are willing to give a discount for ordered parts or some are giving some money.

## Conclusion

It was seen, as expected, that the improved concepts of the continuous project of the bachelor and master course are fulfilling the requirements mentioned above.

The project brings all former taught lessons together and is used in a real project. New knowledge is worked out by the students, such as handling complex projects. The differences of the bachelor and master project are the levels of the tasks and the complexity of the project management as well as the data transfer between the sub teams.

No project was repeated again, which makes it always interesting for the students and the lecturers and makes it easy to motivate all included persons. This was seen at the processes during working at the projects. The results, such as methodical benefit, increased knowledge, management abilities were even better than expected. One reason is the high motivation of the students, because they are not only dealing with conventional lecture and exercises. They have to work self driven and can focus on their own points of interest in the range of the project.

Not only the concept is sustainable, but also even the results of the projects work too. For example, the bicycle test station will be developed further on during the next semesters and the vending machine will be in use during celebrations, conferences, exhibitions etc.

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