# 2006-1284: HOW TO PROVIDE FIRST-YEAR-STUDENTS WITH A REALLY GOOD START INTO THEIR STUDY PROGRAM

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# How to provide first-year students with a really good start to their study program. An innovative and effective approach to the course which includes both active and collaborative learning techniques.

Abstract

Three factors have motivated reforms in the teaching of engineering in the last few years: the demands of industry, concerned faculty members and also recently by recommendations made in the European "Bologna Process". The Technische Universität Darmstadt decided to try to meet the requirements of these reforms by introducing an innovative project-based course entitled "Introduction to Mechanical Engineering". The aim of the course and its new conceptual design is to provide first-year students with an excellent start to the Mechanical and Process Engineering program. This paper wishes to describe and evaluate the course. An analysis of cohort data revealed that students who participated in the course show lower dropout rates and are more likely to graduate than the students who did not participate. The evaluation study focused on the course objectives and teamwork abilities and demonstrates for example that participating students improve their teamwork ability to a much greater extent than do non-participants.

We therefore think that including this project-based course in the program of study will have an important impact on the teaching and learning of mechanical and process engineering. When the course was evaluated, the results demonstrated the benefits of the course very clearly. Participating in the course helps students to develop teamwork abilities and other learning skills of great value to them for further studies and for their professional future.

## I. Introduction

Students who leave engineering programs typically do so during or immediately after their first year of study[1]. If one wishes to keep students in the program, the first year is crucial. A study of dropout rates in 2002[2] showed for example that the dropout rate for all engineering programs at German universities is on average 40%. There are many studies that deal with the reasons for dropping out of a program. According to a study by Seymour and Hewitt[3] dropping out of science, maths and engineering programs is strongly affected by "lack of interest in science" (and engineering) and "poor teaching practices".

When students of the former Mechanical Engineering program (degree: Diplom) at Technische Universität Darmstadt evaluated their department in 1997 they also criticized similar aspects of their study program[4]. Faculty members used this opportunity to make

changes in their curriculum. This was also motivated by demands from industry[5], and by recent recommendations in the European Bologna Process.[6] Since the fall of 2000, students at the Technische Universität Darmstadt have been able to enroll in reformed "Bachelor´s and Master´s programs" (degrees: Bachelor and Master of Science).

The European Bologna Process

In 1999 Germany and 38 other European countries signed the *European Bologna Declaration* in which they committed themselves to realizing the following objectives by 2010:

- the adoption of a system of easily comprehensible and comparable degrees based on two main cycles: undergraduate (Bachelor) and graduate (Master)
- the establishment of a system of credits
- the promotion of mobility by overcoming obstacles to the effective exercise of free movement
- the promotion of European co-operation in quality assurance
- the promotion of the necessary European dimensions in higher education

Theses objectives require the reform of the German higher education system, in particular the adoption of new "Bachelor´s and Master´s programs".

One of the results of the changes in curriculum was the development of an innovative project-based course entitled "Introduction to Mechanical Engineering" (IME) which was first implemented in 1998. The course approach includes both active and collaborative learning techniques. Teamwork ability plays an important part in the project. Overall IME aims to provide first-year students with a really good start to their mechanical and process engineering program at the Technische Universität Darmstadt.

This paper will describe some of the key aspects of the concept of the project-based course IME. First-year students´ cohort data was analyzed in order to examine the possible impact of participation in the project with regard to dropout rate and study success. Furthermore important evaluation work has been done on the course which took place in 2004.

The evaluation study of IME is part of a broad-based research project of the Department of Mechanical Engineering. It is funded by an institution founded by German industry by the name of the "Stifterverband für die deutsche Wissenschaft". It has activated a special program within the context of the Bologna Process in order to support outstanding faculties with regard to their further development. In the context of the evaluation study various research questions were investigated and the statistical evaluation is still in progress. For this paper some of the study's first results will be presented:
Was it possible to achieve the intended course objectives? Which skills and abilities do the participating students learn and acquire?

## II. The concept of the project-based course "Introduction to Mechanical Engineering"(IME)

### Course objectives

The departmental evaluation in 1997 revealed certain deficits in the former Mechanical Engineering program. The following goals were to be achieved by the implementation of the new introductory course IME:

- to introduce the students to the disciplines of mechanical and process engineering
- to enable more contact between students and faculty staff
- to keep students´ interest in engineering from waning while they take undergraduate courses (undergraduate courses such as mathematics and physics were criticized as being boring and not sufficiently application-oriented)
- to help students who have doubts to make the right decision as to whether to stay or whether to drop out of the program as early as possible
- to enhance study motivation
- to give the first year students an introduction to the methodology of mechanical engineering design
- to demonstrate to students what their future job could be like
- to introduce active learning techniques
- to offer students the opportunity to acquire and put teamwork ability into practice (for example communication within a team, listening to others, teamwork techniques, skills in problem solving and presentation)

Overall it was hoped that the dropout rate could be reduced to a minimum, hence the course was positioned in the first year of study to benefit the students at the earliest possible stage.

### Course description

The course is designed to include active as well as collaborative learning techniques. In addition to the technical content teamwork ability plays a very important part in the concept. Participation in the course is voluntary – it is usual for about 250 students to participate each year. The course is held a few weeks after the beginning of the year of study. Teams of about ten students have one week to solve a technically challenging engineering problem. No other classes take place during the project week. The student teams are put together coincidentally, that is to say that the team members do not usually know each other (this is confirmed by 70% of those who evaluated the course.) As the participants are just beginning their studies one can assume that they do not have a great deal of experience in working as a team. In the evaluation study the students who participated were asked to estimate the amount of experience they had had in working in a team to date. About 40% of them said that they had had some, the others said little or none.

Finding an adequate engineering problem each year is always a challenge. The task has to be motivating, sufficiently complex for a week of teamwork but at the same time not too difficult for first-year students. The task is to be relevant to society in order to demonstrate the importance of engineering for our future world. The motto of the course is an Archimedes proverb: "Give me a place to stand and I will move the world" which is a prosaic version of the "law of the lever" with which all engineers are familiar. The task has to leave a variety of possible solutions open for about 20 different student teams and should include distinctive disciplines of the program. The following gives an example of the IME task of 2005.

Engineering problem of IME 2005

Reduction of particulate matter in the environment seems to become a major source of profit for enterprises who can offer systems for the removal of particulate matter from the municipal environment or from devices emitting particulate matter. The strategic goal set by the board of directors of your enterprise is to be the leading supplier of particulate matter removal systems with a share of at least 30 % of the world market.

The mechanical engineering department of your enterprise has been assigned the task of designing 25 different systems for collecting particulate matter either from the municipal environment or directly from devices emitting particulate matter. Your group's task is to design one such system.

Here are some examples of products designed by the student teams:


Figure 1: Picture of a filter system integrated in a tram designed by one of the teams (IME 2005)

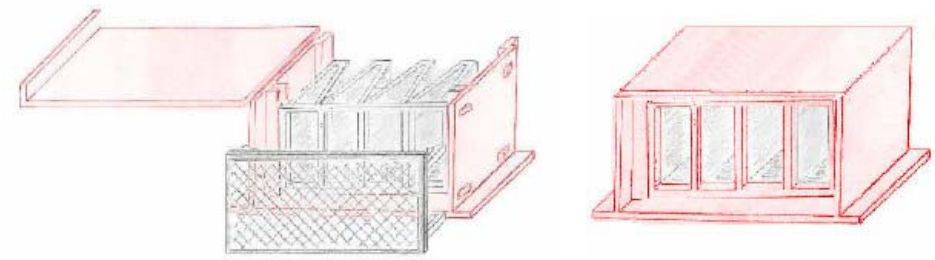

Figure 2: Drawing of a filter system designed by one of the teams (IME 2005)

Various kinds of *support facilities* are offered to the student teams:

1. A *support team*, consisting of an engineering assistant and a coach (a student with psychological training) is assigned to each student team. The assistant supports the students with technical aspects concerning the given problem. The coach assists the use, acquisition and development of teamwork ability. They also alternately supervise the team, give feedback and guide members of the team to reflect their teamwork. For example the assistant gives them feedback on how they are proceeding methodologically, the coach supplements this by talking about the teamwork techniques they are using or the way they communicate or behave during discussions. However, in general the

students should learn how to solve problems themselves or with the help of their team. They should also learn how to acquire knowledge which they lack in order to be able to solve a given task within a given time frame. Before the beginning of the project- based course each support team receives intensive training supervised by members of the Didactic Center of the Technische Universität Darmstadt.

2. The help-desk is a support facility for all kinds of questions that may come up during the week. It provides information and material relevant to the topic of the given task and assistants from the Faculty of Engineering are also present to help the students find answers to their questions.

3. They can ask the professors questions: All the professors of the department offer their support to the students for one full morning. Thus the students can get into contact with the professors: They ask questions, discuss their technical problems and sometimes even realize that they know more about their topic than do the professors.

4. In addition to this the students are supposed to use libraries and search the internet to obtain the information required.

The project-based course concludes with a presentation of the solutions of all teams in front of the faculty.

The following pictures should give an impression of some aspects of the course.

Figure 3: Pictures of asking professors questions (left) and of teamwork (right)

A distinctive feature of the course is its *interdisciplinary nature*: The IME course has been developed in unique and close collaboration between members of the Department of Mechanical Engineering and members of the Didactic Center of the Technische Universität Darmstadt. The team in charge of organizing and carrying out the course has always been and will continue to be made up of engineers and members of the Didactic Center. The support team is also interdisciplinary. A more detailed description of IME can be found in Hampe and Görts[7].

Teamwork ability

Why is teamwork ability so important? What is teamwork ability and how can it be acquired during the IME course?

According to Behrenberg and Fassnacht[8] the concept of teamwork ability has two meanings: On the one hand it is the ability of the team itself to collaborate successfully. On the other

hand it is the ability of each team member to contribute to the success of the team´s work. They emphasize that certain conditions must apply if the team is to function as a competent one. The atmosphere in the team has to be free of angst; there has to be good communication and co-operation between the team members; the team members should support each other with regard to their personal development and should make full use of all the creativity and diversity that exists in the team; the task has to be sufficiently complex so that the team really needs all their resources to find a solution to the task. Thus, the success of teamwork, according to Behrenberg and Fassnacht[8], depends on the task, the cooperation and communication in the team, the working methods and on the supervision. The supervision supports the team structure and helps to reflect the (team) work.
The abilities which enable people to work successfully and efficiently in teams also play an important part in the requirements indicated by industry and in the recommendations made in the European Bologna Process. The IME course was designed and implemented in order to provide students with a really good start to their study program and in addition to offer them an excellent education and preparation for their professional future.

Therefore the course IME aims to create a learning environment, in which the conditions postulated by Behrenberg and Fassnacht[8] are achieved: about ten students form a team and are given a challenging problem which can only be solved with the help of all the team members. The teams imitate professional teams the industry: Tasks are broken down and each sub-task is assigned to one and only one team member. The individual team member has to feel responsible for delivering important results back to the team. The time frame for a solution is limited: not more that one week. With the support of the engineering assistant and, even more essentially, the support of the coach, the students experience a learning environment in which they are able to develop, practise, reflect and improve their teamwork abilities.

## III. Analyzing cohort data

Usually about 50% of the first-year students participate in the project based course. In recent years the number of first-year students has been turned out to be very high, as high as 630 in 2004. Due to the lack of capacity (problems with space, resources and finance) only 250 students were able to participate in IME. However, it is intended that all first-year students will be given a chance to participate.

As participation is voluntary one can divide the cohorts of first year students into IME-participants and non-participants. Hence cohort data received from the administrative department was analyzed with regard to dropout rate and study success in the form of passing the "*Vordiplom*". The German "*Vordiplom*" consists of the examinations which are supposed to be taken and passed after four semesters (2 years) of study. The analysis of cohort data includes cohorts of first years from 1998 until 2002. We chose these cohorts because IME was introduced in 1998 and the cohort of 2002 offers a three year time span of examining the data until the time of measurement (November 2005).

### Dropout rate

Figure 4 shows the dropout rate of IME-participants and non-participants for each cohort. The differences in dropout rate can be seen very clearly and are highly significant.

Accumulated over the cohorts 1998 until 2002 the dropout rate turns out to be 22% (IME-participants) compared to 58% (non-participants).

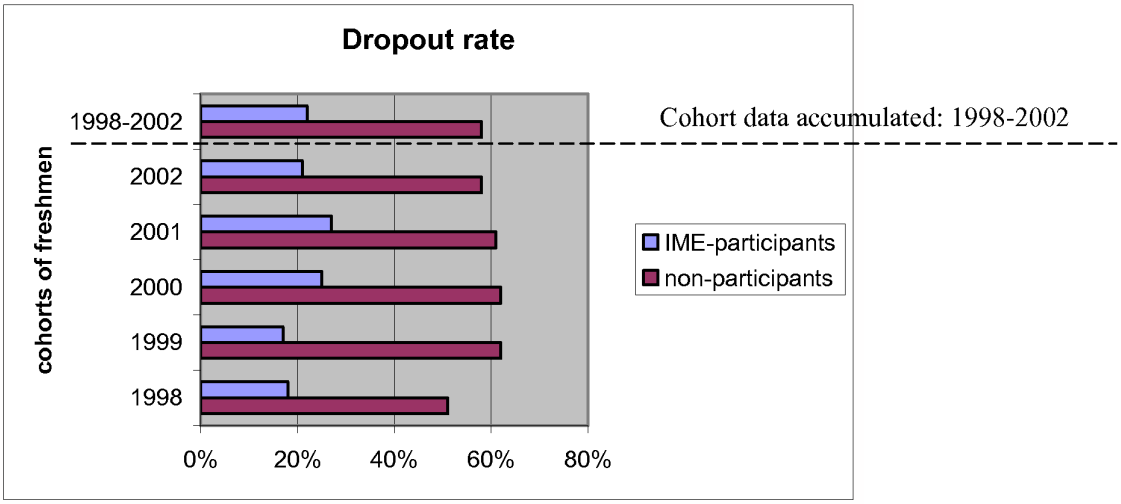


Figure 4: Dropout rate of IME-participants compared to non-participants.

We have accumulated the cohort data from 1998 until 2002 for the following: The effects of the single cohorts show the same results with only small tolerances.

Another way of illustrating the difference of dropout between the IME-participants and non-participants is shown in figure 5. The general trend over all terms stays the same: the percentage of non-participants who drop out of the program is continually higher than the dropout rate of participants. It can be seen that 33% of the non-participating group drop out of the program as early as the end of their second term while only 6% of the IME-participants do so.

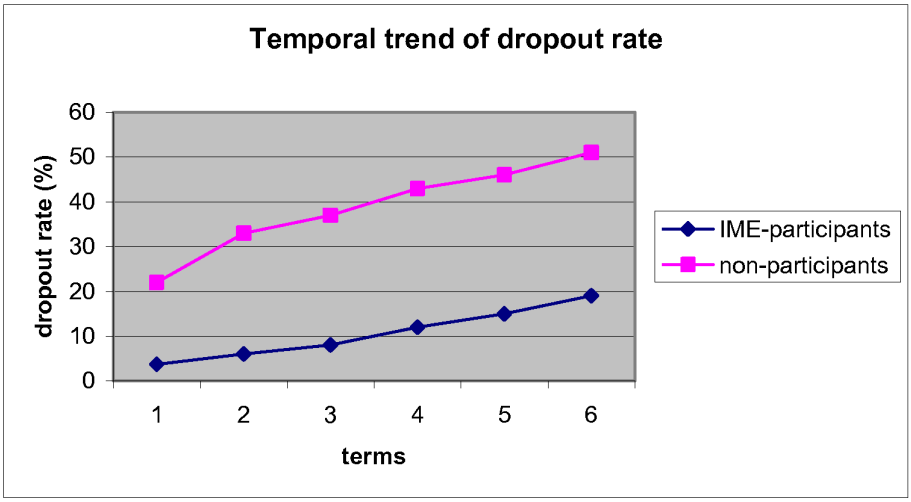


Figure 5: Temporal trend of dropout rate

Study success

Similar effects can be presented for success in studies. Figure 6 illustrates the temporal trend of passed "*Vordiplom*" for IME-participants and non-participants. The difference is already apparent after the fourth term: 29% of IME-participants passed their "*Vordiplom*" but only 12% of non-participants.

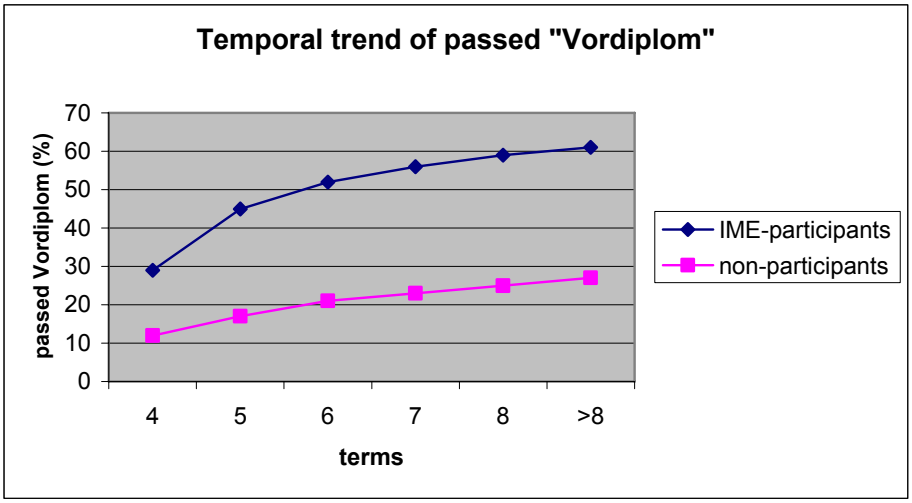


Figure 6: Temporal trend of passed "*Vordiplom*"

Analyzing cohort data revealed that students who participated in the course (IME participants) show lower *dropout rates* and are more likely to pass their (*Vordiplom*) than the students who did not participate (non-participants). Therefore the project-based course seems to be having a significant impact on the further studies of students from the Mechanical and Process Engineering program. Although it would be easy to conclude that the participation in the project-based course had caused the differences described, the authors would like to warn their readers against drawing such easy conclusions. In the context of the IME evaluation study one of the authors has collected data which will help to classify the effects that are caused by the project-based course and/or by other factors (influence of self-selection). The author is at present in the process of analyzing the data, so further results about the possible influence of the self-selection variable will be available in the future.
The following section about evaluation will present some results concerning the achievement of the course objectives and the acquisition of teamwork abilities.

## IV. Evaluation

The evaluation of IME 2004 included two different questionnaires. The questionnaire *"course objectives"* wished to try and find out whether the course achieved its goals. This questionnaire was handed out on the last day of the project to participants only. In addition to the course objectives, the questionnaire also asked students how satisfied they were with the course and about some other things: for example the organization of the course, the support facilities, the engineering problem or the room situation. These questions were analyzed in order to improve the project-based course.

The questionnaire *"teamwork ability"* was given to both participants and non-participants. This was realized shortly before and after the course as a *pre-posttest-design*. The results were analyzed with regard to course participation and focused on the improvement of teamwork abilities. Both questionnaires were developed by one of the authors.

Results: questionnaire "course objectives"

240 students participated in the project-based course in 2004 and answered the questionnaire. Ratings could be made on a scale from 1 to 5 (1=I do agree… and 5=I do not agree… with the given statements). Here are some of the most interesting results:

- 70% of the participants claimed that they did not know any members of their team before participating in the course.
- 77% of the participants claimed new friendships with some of the team members resulted.
- 75% of the students said that they think they now have a better idea of the distinctive disciplines of mechanical and process engineering.
- 90% said they think they now have a better idea of their future job might be like.
- And 90% stated that their study motivation has increased.
- One of the goals was "to help undecided students to make the decision whether to stay on or whether to drop out of the program as early as possible". For 17 of the participants this goal was achieved: they planned to drop out of the program after participating. This result is very important for the students and the faculty because an early decision is advantageous to both sides: the students do not lose any valuable time and the faculty saves resources.

Generally spoken the majority of the course objectives listed above were achieved.

Results: questionnaire "teamwork ability"

On the basis of existing literature and in close cooperation with the people responsible for the project, one of the authors has postulated three categories of teamwork ability which are important for successful teamwork: (a) (technical) problem solving; (b) functioning/structuring of the team and (c) relationships/atmosphere within the team. Figure 7 shows the three categories.

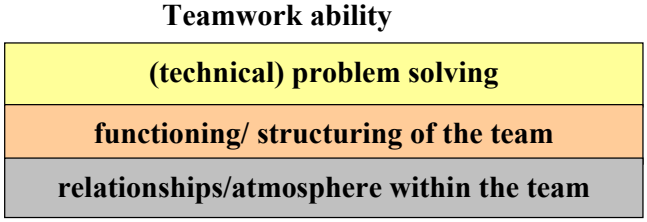


Figure 7: Three categories of teamwork ability

In the questionnaire the teamwork ability was operationalized into a number of statements. The students read the statements and had to decide whether they could agree with the statement or not.
Here are some examples for such statements:

- *"If I don´t understand something, I ask the other team members"*
- *"I propose creativity techniques if they seem to fit in"*
- *"I try to visualize work results so that I don't lose important information"*

In 2004, 630 first-year students started studying Mechanical and Process engineering. 433 of these answered the questionnaire. Ratings could be made on a scale from 1 to 5 (1=I do agree… and 5=I do not agree… with the given statements). In order to analyze whether an improvement in student ratings concerning their teamwork ability could be observed, the method was as follows: As a first step the postulated categories were confirmed statistically. Second all the ratings of the posttest (after the course) were subtracted from the pretest ratings (before the course). Finally t-tests (one tailed) were applied for these calculated values. Table 1 provides the 3 categories and an indication as to whether the values turned out to be statistically different according to the hypotheses.

| **categories of teamwork ability** | **Statistically different ($p < 0.01$)** |
|---|---|
| (technical) problem solving | Yes |
| functioning/structuring of the team | Yes |
| relationships/atmosphere within the team | No |

Table 1: Indication whether the values turned out to be statistically different ($p<0.01$)

The group of IME-participants showed a significantly higher improvement in two of the three categories of teamwork ability: They stated that they had acquired more problem solving ability as well as more ability with regard to the structure and functioning of the team.
The coaches who supported and observed the student teams were asked to fill out a brief questionnaire at the end of each project-day. The evaluation of their observations about the development of the team as a whole confirm the results stated above.
Just recently the questionnaire *"teamwork ability"* has been given out for the third time (second post test): The same students were asked to fill out the questionnaire about teamwork ability a year later. It will be interesting to analyze what has happened to the participants´ ability to work in a team after a full year's study.
One intensive week that offers a learning environment in which close collaboration and active learning is encouraged seems to be an excellent way of providing students with a really good start to their course of study.

## V. Conclusion

Since 1998, when the project-based course was introduced for the first time, it has become an essential element of the curriculum and the Faculty is continually at work on improvements. The results we have presented confirm that the course does in fact achieve its objectives and also show how the course is of real benefit to the students. They become much more able to work in a team and then, when they encounter real challenges during their study courses they can make better use of collaborative learning environments. This also applies to their professional future. However, we recommend that long-term evaluation continue. This will enable us to continue monitoring the effects on students´ teamwork abilities and also on the impact of the course on their continuing success in their studies; in addition we can also monitor the job-related behavior of course participants.

The presentation of the cohort data analysis showed clear differences between IME-participants and non-participants with regard to dropout rate and success in their studies. The

data presented also confirms the claim made by Wankat and Oreovicz: [1] i.e. that many students who leave engineering programs do so during or immediately after their first year. The differences with regard to dropping out after the first year of study underline the importance of shaping a particularly good first year of study.
One of the authors is at present in the process of analyzing the data collected within the context of the IME evaluation study. Hence we intend to present more results soon in order to classify the effects that are caused by the project- based course or by other factors.

Many universities in Germany and in other countries now have to face the task of reforming their courses of study. The project-based course "Introduction to Mechanical Engineering" has proved to be successful and has multiple benefits. One must however admit that a very considerable amount of work and resources are essential in order to hold the course annually. The whole department has to be committed to the project, this too is essential. We hope that by sharing the information we have presented here we might be able to give other universities or institutions ideas and advice which might encourage them to plan and implement a similar project-based course.

## VI. Acknowledgements

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