# INTEGRATING FORMULA STUDENT INTO DESIGN EDUCATION – BRIDGING THE GAP BETWEEN THEORY AND PRACTICE

**Fabio DOHR and Michael VIELHABER**
Institute of Engineering Design, Saarland University, Germany

**ABSTRACT**
Design methodology is a rather abstract, yet very important, aspect of engineering design. This leads to the acceptance of such topics in education being rather low among students. The combination of theoretical contents and practical courses is a very promising approach to learning how to benefit from the use of design methodology and thus being able to estimate it. In this paper a concept is presented on how such a combination of theory and practice can be realized. It is based on the integration of student competitions – in particular Formula Student – into different courses of engineering design education ranging from examples in lectures to development projects in practical courses. Apart from these aspects students are being motivated to participate in student competitions and learn to apply a structured development process and appropriate methods in their daily work.

*Keywords: Theory and practice, design education, Formula Student*

## 1 INTRODUCTION

Engineering design education is based on theoretical methodologies which in most cases seem very unfamiliar to students. Hence the acceptance and application of those methodologies by students is rather low [1]. This often leads to unsatisfying results for both students and teachers. This problem is intensified by the fact that courses in which students have to apply the theory on their own are rare in academic teaching, especially during bachelor degree courses. Thus students do not learn how to transfer and apply their theoretical knowledge. Nevertheless, engineering design education will become increasingly important in the future [2].

A very effective possibility to encourage students to apply their theoretical knowledge on practical development projects are student competitions. Popular examples of international competitions are Shell Eco-marathon [3], Robocup [4] and Formula Student [5], which is of particular interest in this paper. In addition to applying their knowledge and thereby deepening it, students gain skills beyond what is taught at university – e.g. team work, project management or marketing. Beside those positive effects the main drawback is the time students have to spend on such a competition in addition to their regular studies – without earning ECTS credits for it. Thus only few enthusiasts are motivated to take part in such a student competition and in many cases the study achievements suffer from in return.

In order to address those issues mentioned above, a concept for the integration of student competitions into academic education is presented in this paper. It is based on the experience of the authors with the student competition Formula Student and is intended to closely interlink education and student competitions in order to generate mutual benefits: improving education and encouraging students to participate in such competitions.

In the next chapter contents and challenges of the student competition Formula Student are explained. In chapter three the concept for the bilateral integration is presented. Subsequently, this concept is evaluated based on a survey among students who participated in the respective courses. Finally, conclusions and further ideas for the improvement of the concept are presented.

## 2 FORMULA STUDENT

Formula Student is an international student design competition which originates from the Formula SAE [6] which has been organized by SAE International [7] since 1979. It has been adopted by several national institutions of engineering, e.g. in the UK and in Germany. The goal is to design and build a single-seat racing car – like the one depicted in figure 1 – under real market conditions. In addition to the technical aspects, students have to administer the team as a small company which requires management, marketing, sponsoring and people skills. In this way students gain experience in industrial practice and broaden their scope to a holistic view of product development, not only focusing on their area of specialization.


*Figure 1. Formula Student car SRCe01, Saarland University, 2012*

During several events the teams have to compete in both static and dynamic disciplines. In dynamic disciplines – e.g. acceleration and endurance race – the performance of the car is rated and in static disciplines – e.g. business plan presentation and engineering design event – the engineering design process, the technical implementation and innovativeness as well as the business plan are judged.
In 2011 the authors initiated the foundation of a Formula Student Electric (FSE) team – a subcategory for electric drives – at their university. Currently the team size is about 30 people which is – although still growing – rather small compared to other teams. Hence the average time spent on the project by each team member is quite high – about 20 hours per week. Such a high work load for the team members inevitably leads to a negligence of their studies. That has been one of the reasons for the authors to develop a concept for the integration of student competitions – in particular Formula Student – into academic teaching. This will be further elaborated on in the next chapter.

## 3 INTEGRATION OF FSE AND TEACHING

### 3.1 Concept of integration

Formula Student projects are popular at technical universities to support students both to apply theoretical knowledge acquired on realistic practical examples and to acquire additional skills not taught in university courses. They are meant to be self-organized student projects only loosely supported by university faculties.
The approach presented in this paper goes beyond the common passive support. While retaining the project's independence, it identifies and fosters opportunities for mutual support between the university education and Formula Student project side.
University education is generally composed of different types of courses. The technical and conceptual foundation is laid in theory-oriented lectures, which may be supported by practical courses. Practical projects are gaining acceptance in technical disciplines to prepare students for project and team work. Seminars foster team exchange and scientific presentation skills, and bachelor and master theses are supposed to build and show the capability for guided but self-reliant scientific work. University programs are generally designed to be full-time.
Formula student projects build on knowledge acquired (at least partially) through these university courses. However they require a multitude of additional competencies, generally to be acquired on a learning-by-doing basis: soft skills such as project management or sales presentation techniques and interdisciplinary skills such as marketing or finance planning being just some examples. Thereby they offer a second, complementary but independent education stream. For successful results, however, they require significant project effort from the students involved.

Figure 2 contrasts the targets of both education streams with each other. It complements requirements generally set by the industrial job market, which combine technical and non-technical skill sets, generally only partially met by the university education side alone.

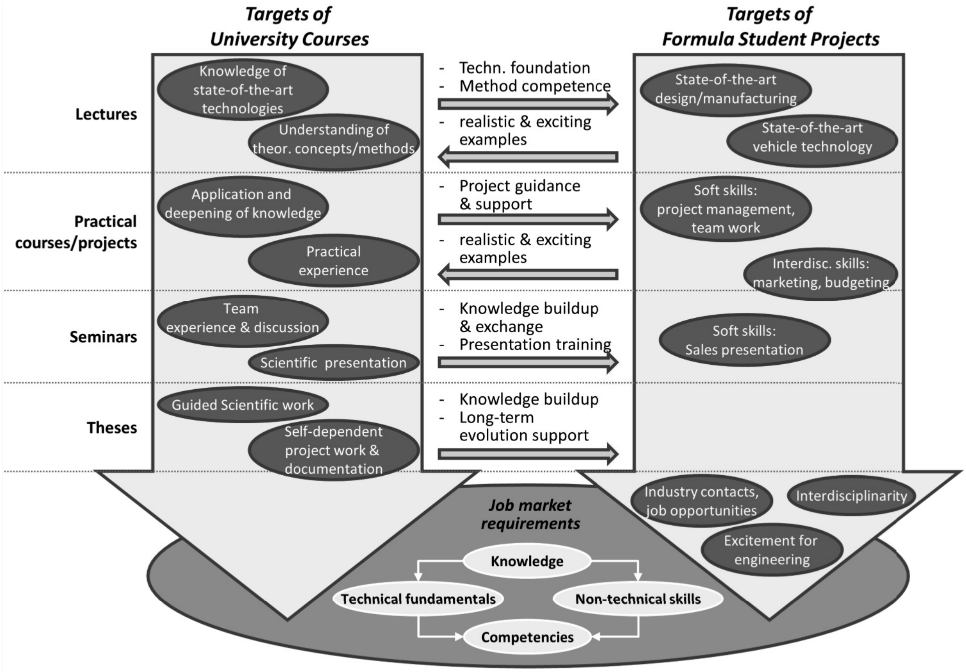


*Figure 2. Integration concept (content partially adapted from [5], [8], [9])*

To better interlink both education streams and to derive efficiencies and synergies towards a better job market fit of the students, different course types have been investigated regarding what they could offer to the project work on the one hand and gain from it on the other hand. It was an important pre-condition though that the general character as well as the theoretical and methodical standard of the different course types were not changed.

## 3.2 Integration by course type

Courses of each type have been adapted in accordance with their specific character. Due to the authors' university focus, main adaptations have been made in the area of product development and engineering design. In the following, integration concepts will be described and examples given from the authors' experience. Figure 2 also shows the mutual benefits for university education and the project side.

### *3.2.1 Lectures*

No specific lecture has been set up to solely convey Formula Student technology knowledge, as this would have contradicted with the self-reliant and student-led character of the Formula Student project. However, technological and methodical project requirements have been considered in the selection of lecture topics, and examples from the project work have been integrated into the lectures and accompanying practical courses.

For example, on the technical side, electric engine types have been discussed with regards to FSE application. On the methodical side, FSE has been used extensively as an example in design methodology lectures. Doing so stimulated the students' interests and theoretical knowledge could better be transferred due to the concrete nature of the example.

#### 3.2.2 Practical projects

In engineering design education, practical projects play an important role in offering the students an opportunity to apply and practice theoretical concepts and methods on exemplary development tasks. Success of these courses heavily depends on the level of realism of these tasks. They may tend to be too simplified to be taken seriously, too complex to be sufficiently solved within a given period of time, or too elaborate or costly to be physically realized, in the end.

In this respect, formula student projects can offer ideal tasks for such practical projects. They consist of a multitude of development tasks of any desired size. They pose real requirements which are technically and financially realistic, depend on the successful realization of the project results and can thereby show the project's success (or failure) not only on paper, but on the realized product.

The FSE project at the authors' university was kicked off through such a practical project course, in which the basic engine concept for the race car has been developed. Follow-up projects supported component developments of battery and drivetrain modules.

#### 3.3.3 Seminars

Seminars offer the possibility to support students in building up knowledge in a limited area and in sharing this knowledge through presentation and discussion. They can therefore be an ideal means for Formula Student projects to formalize knowledge build-up within the project team. Seminars may address topics which might otherwise not be able to be addressed due to limited project resources.

For example, the authors held a seminar regarding Formula Student car technology, which initiated a documentation standard for knowledge exchange within the team. Other topics were advanced engineering IT tools such as multibody or fluidic simulations and their Formula Student-related potentials.

#### 3.3.4 Theses

In bachelor and master theses, the students shall prove their ability to perform guided scientific work on an engineer's level. Topics generally come from internal research projects or industrial project cooperation. Formula Student projects can be an additional source for such theses. While the core project generally has to focus on shorter term design topics, theses can address long-term aspects which are beyond scope from a short-term view, but help the project tremendously regarding its long-term competency evolution.

At the authors' institute, Formula Student-related theses have for example evaluated potential for the use of carbon-fibre-reinforced plastics and methodically developed battery design and battery management concepts for electric race cars.

## 4 Evaluation

In order to evaluate the concept and its acceptance by students, surveys have been conducted in the courses in which the concept has already been applied. Apart from various theses, over the last two years these include:

- student development projects
- practical courses
- seminars
- lectures including small student development projects

### 4.1 Survey

The surveys focused on the acceptance of the methodology and the FSE examples by students. Furthermore students could comment if this combination of theory and practice has been helpful for them.

In figure 3 the results of the surveys are summarized. The results are separated into non-members (green, upper bar) and members (red, lower bar) of the Formula Student team. Among the non-members more than 50 percent stated that the chosen examples have been helpful for them and almost 80 percent considered those examples more useful than any notional ones. All of them stated that the concept has awaken their interest in engineering design and still more than half of them show an interest in the student project. Overall, two thirds of the non-members appreciated the concept as an improvement of the course.

The responses from the members of the Formula Student project who participated in one or more of the courses have been very positive. All of them considered the examples more useful than the common notional ones and each of the students appreciated the concept in the courses as an improvement. Moreover, all of the members who participated stated that their project profited from the course concept and that they will give more attention to the use of design methodology in the future.

Regarding the suitability of the concept presented for different kinds of courses, students especially considered practical courses and student development projects most suitable. Most of the students stated that the concentration of lectures on student projects is not preferable but using examples to clarify contents would be very helpful.

One interesting aspect is the attitude towards theses: among the non-members only about 55 percent of the students would prefer the integration of student project aspects into theses. But among the members this has been stated by 100 percent.

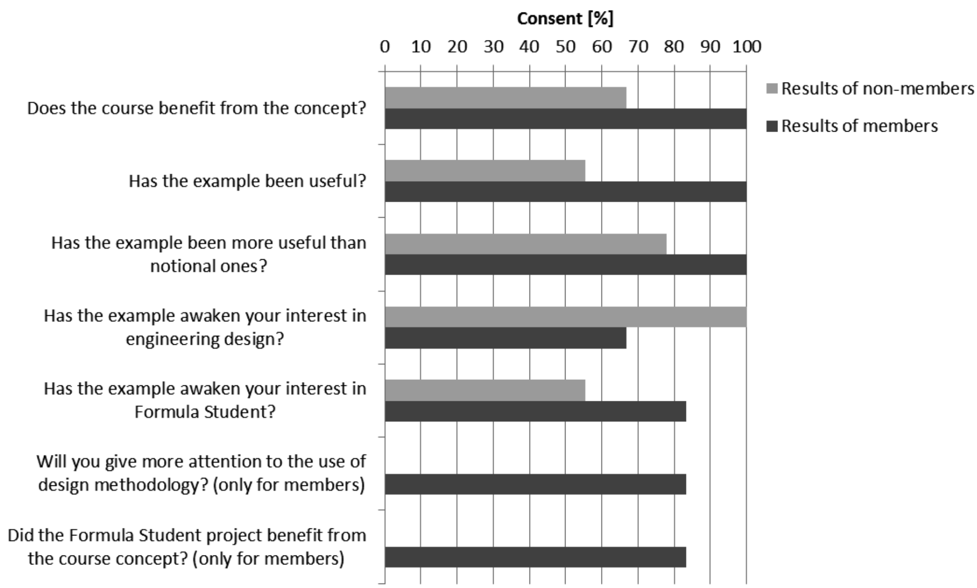


*Figure 3. Results of the survey across several courses*

### 4.2 Discussion of the results

The results of the survey show that the concept has a positive effect on the interest of students and their acceptance of theoretical contents. Unfortunately none of the students who took part in one of the courses and who was not a Formula Student member before has chosen to take part in the competition. This might be reasoned in the early phase of both the concept and the Formula Student team structure at Saarland University – at least to some extent. A more mature team structure and a more consistent integration of the concept in teaching will hopefully improve this aspect. Future surveys will provide feedback on that.

One very positive aspect is the feedback of the team members who participated in one of the courses. They now apply the theoretical aspects of the courses in their daily work and in this way they are able to improve their development process – which finds expression in the reduced development time of their current Formula Student car by about three months for example.

## 5 CONCLUSION

Engineering design is a very important field in the education of future engineers because it will become increasingly important in industrial practice. In order to foster the acceptance of such a theoretical field among students, a concept for the integration of student competitions – in particular Formula Student – into engineering design education has been developed. The evaluation among the students who participated in the respective courses has shown that the intended bilateral benefits emerged – both the courses and the student project could be improved.

In the future the concept will be further improved based on the feedback of the students. Additionally, further disciplines will be involved – e.g. actuation technology, electronics and control engineering. In this way it is intended to sensitize students with regard to a consistent mechatronic systems thinking.

Furthermore it is conceivable to integrate different faculties which would broaden the skills of students beyond the classical engineering disciplines.

In order to prepare students for collaborative design distributed over several locations, there currently are efforts underway to establish a collaborative course with another university. This collaboration is based on the Formula Student teams of both universities which already established a successful cooperation.

## REFERENCES


[1] Vielhaber, M., Dohr, F. and Lüdeke, T. School Culture Through Praxis. In *International Conference on Engineering and Product Design Education (E&PDE) 2012*, Antwerpen, September 2012, pp. 147-152 (The Design Society, Glasgow, Institution of Engineering Designers Wiltshire).

[2] Razzouk, R. and Shute, V. What Is Design Thinking and Why Is It Important? *Review of Educational Research*, 2012, 82(3), *330-348.*

[3] http://www.shell.com/global/environment-society/ecomarathon.html, last visited: 2013-02-21.

[4] http://www.robocup.org, last visited: 2013-02-21.

[5] http://www.formulastudent.com/, last visited: 2013-02-21.

[6] http://students.sae.org/competitions/formulaseries/, last visited: 2013-02-21.

[7] http://www.sae.org/, last visited: 2013-02-21.

[8] Kottkamp, E. Anforderungen der Industrie an die Ingenieurausbildung. In *Qualitätsdialog Ingenieurausbildung*, Bonn, October 2007.

[9] Wucherer, K. VDE-Grundposition zur Ingenieurausbildung. In: *Kolloquium des Hochschullehrerverbandes*, Juni 2002.