# TUTORIAL SUSTAINABLE INNOVATIONS - AN INNOVATIVE ROLE-PLAY CONCEPT FOR EDUCATION

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## ABSTRACT
Developing sustainable products is no easy task. For designers, this means that not only technical requirements for functional performance but also ecological, economic and social requirements have to be met. Besides comprehensive knowledge in the field of sustainable product development also persistence is demanded. This is due to the fact that designers often have to defend sustainable solutions more intensively than conventional solutions, so that decision makers in companies do not reject solutions prematurely for instance due to higher manufacturing costs. Therefore, a course at the TU Darmstadt was set up which has the goal to not only impart knowledge to the students in the field of the development of sustainable products but also to deliberately introduce them to coporate daily life. This Tutorial Sustainable Innovations (TutSI) is based on an innovative role-play concept, in which students work in interdisciplinary teams and have to present and defend their solutions in regular quality gates to a management board of a fictive company. Moreover, students learn how to integrate all three dimensions of sustainability into the design process from the beginning.

*Keywords: sustainable innovations, design for sustainability, role-play*

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# 1   INTRODUCTION

Sustainability more and more has come to an important role in all types of companies. Beside the installation of sustainable structures by means of Corporate Social Responsibility, sustainability aspects also increasingly have to be integrated in the product development process.

The classic definition of sustainability is described in the Brundtland Report (United Nations, 1987): a development is sustainable that meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition is based on the three dimensions of sustainability that relate to the ecologic, economic and social impacts of human activities. As technical products with their production, use and disposal have a significant effect on our life and environment the demand for holistically improved products is particularly urgent.

Therefore gradually more laws and labels exist that contain environmental requirements for products (Council of the European Union, 2009 and 2010). Moreover, companies increasingly decide to proactively develop (Birkhofer et al., 2012) sustainable products that have to meet - beside technical requirements for the function fulfillment - requirements derived from the 3 dimensions of sustainability, namely ecological, economic and social requirements (see figure 1).
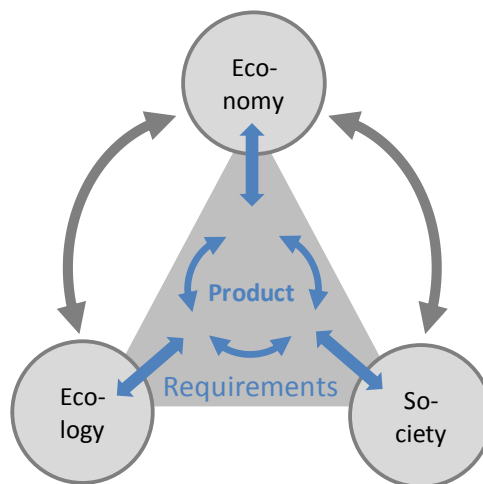


*Figure 1. The three dimensions of sustainability*

As designers have to meet a lot of additional requirements, the development of a sustainable product is no easy task.

Therefore, profound knowledge in different disciplines is required. The development of sustainable products needs the integration of all company sectors, as for example the corporate management, the marketing and sales departments. It is consequently recommended to let interdisciplinary teams develop sustainable products (Gaertner, 1999)

The work in interdisciplinary teams can lead to difficulties as from the organizational and social point of view it plays an important role to deal with partly different and unfamiliar working methods of the involved disciplines and to engage with them (Pahl/Grote, 1996).

Usually enormous persistence is required when designers develop sustainable products: even if the goal of developing a sustainable product is set, cost goals usually are prioritized. Therefore, the implementation of holistically sustainable product concepts that take into account environmental, social, economic and technical requirements equally, is often hampered.

Because of the associated problems, it is important to train the development of sustainable products and distinctively prepare students for these challenges.

Therefore, a Master course at the TU Darmstadt, the Tutorial Sustainable Innovations (TutSI), was introduced in which students from different disciplines have to revise products concerning sustainability aspects in interdisciplinary teams.

In order to reflect the everyday business as realistic as possible and to particularly prepare students for the problems in the field of sustainable product design, the course is set up as a role-play: students have to present their concepts at regular intervals in quality gates to the board of management of a

fictional company and systematically have to defend their solutions. The managers then decide on the next steps in the development process, e.g. which concepts have to be further pursued.

In chapter 2, this paper describes the concept of the tutorial with its role-play character, interdisciplinary teams and the learning outcomes. Furthermore, in chapter 3 the working contents of the course and the quality gates are presented. Chapter 4 gives an insight into the examining and grading of the course and in chapter 5 the teaching aids and documents are described. Finally, chapter 6 shows an evaluation of the course and gives an outlook on further possible improvements of the tutorial.

## 2   THE CONCEPT OF THE COURSE

In order to optimally prepare students for the problems that are related to the development of sustainable products the tutorial is realized as a role-play.
Moreover, students work in interdisciplinary teams in order to simulate the daily development work in a realistic way. The elements of the concept as well as the learning outcomes of the tutorial are described subsequently.

### 2.1   The role-play-character

The tutorial is realized as a role-play in order to simulate corresponding situations in subsequent professional life (see figure 2).
The framework is the fictitious enterprise WoodTech AG whose management board sets the target to revise products of the portfolio in terms of sustainability aspects. The basis for the project are real existing products, usually out of the area of household appliance.
While the students represent the project teams of the fictitious "Woodtech AG", the other roles are assigned to the academic staff who organizes the tutorial: 3 research associates of the organizing institute take the role of the management board, while 1-2 research associates take the role of external consultants. These external consultants are members of the workgroup "EcoDesign" of the organizing institute and provide assistance to the student teams in weekly voluntary consultation hours concerning questions about development methods and their use. To encourage independent work and strengthen the student's self-responsibility, during the consultations hours no content support is given. Instead, only questions regarding development methodologies are answered and discussed.
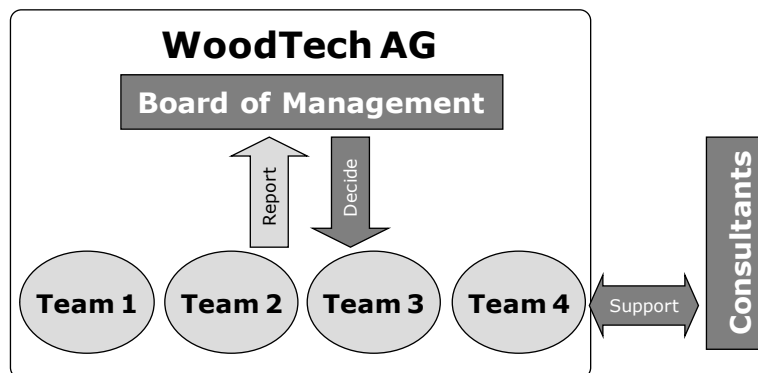


*Figure 2. The role-play-character of the course*

Finally, at regular intervals (usually every 3-4 weeks) the development teams have to present their (interim) results in quality gates to the board of management. In short presentations followed by a question and answer session, the teams have to persuade the board of management of their thitherto developed concepts.
Students are therefore deliberately put in the position of having to defend their (interim) results to critical questions of the board. The management selects specific questions which focus on the problem of the integration of different aspects of sustainability in a product concept. In advance within the board of management different roles are defined and distributed to the academic staff: a commercial director, a chief technical officer and a chief financial officer. While the commercial director is open to sustainability aspects, the chief technical officer having mainly developed the previous product is only

hard to be convinced of innovations. The chief financial officer, however, is mainly to be impressed with numbers.

Modeled on the real everyday business, after the presentations and questioning the management board takes content-based decisions that have to be considered by the teams accordingly during the further course of the development project. It may happen, for example, that the board rejects partial solutions, provides additional claims to a concept or requires that certain steps need to be clarified.

## 2.2 Interdisciplinary development teams

Usually 4-5 teams of 4-6 students of different disciplines, as for instance engineering and natural sciences or social sciences take part in the tutorial. In figure 3, the distribution of participating students in the winter semesters 2010/2011 until 2012/2013 (n=59) to the various fields of study are listed. The high number of mechanical engineering students is explained by the fact that the organizing institute is part of the mechanical engineering department of the university. Moreover, the course is offered at a Technical University, with the mechanical engineering department having the most students. Also, a lot of industrial engineering students having knowledge in the field of economics, take part at the tutorial. Other sciences like education science, philosophy or science of history on the other hand provide rather a small part of students.

At the kick-off event the students are divided in interdisciplinary teams by the supervisors of the tutorial. Only a division by the supervisors can assure that the students from the different fields are distributed evenly among the development teams.
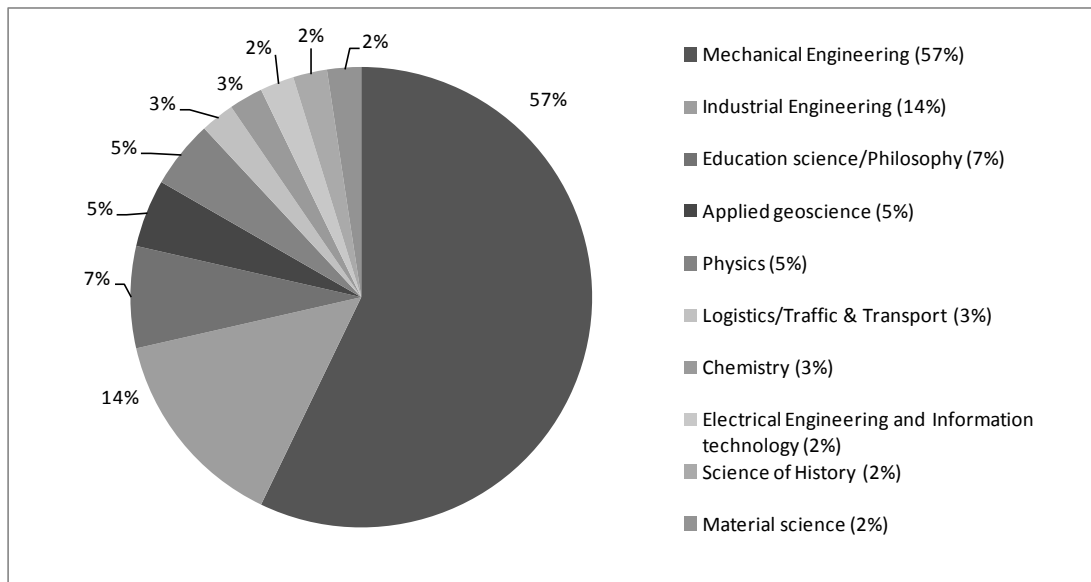


*Figure 3. Students participating in the course*

## 2.3 Learning outcomes

The learning outcomes of the tutorial are summarized in figure 4.

The intention of the tutorial is to prepare the students for the daily development work in an optimum way. Therefore, not only knowledge in the field of developing sustainable products has to be imparted to the students but also skills to implement projects independently and to apply design methods. In addition, soft-skills should be trained by the tutorial like for instance creativity, organization and the adoption of personal responsibility as well as communication and dealing with multidisciplinarity.



*Figure 4. Learning outcomes of the course*

# 3 THE QUALITY GATES AND WORKING CONTENTS

For the tutorial, real existing products, usually out of the area of consumer appliances (such as refrigerators, epilators or leaf blowers) are provided from changing industry partners. For those products the teams realize sustainable concepts both theoretically and practically.

The product is introduced to the students at the beginning of the tutorial during the kick-off by the board of management of the fictitious WoodTech AG. All teams redesign the same product in order to create a competitive situation.

During the kick-off meeting, the formation of the interdisciplinary teams as well as the presentation of the development goals takes place. Afterwards, the teams have to pass through a quality gate process.

Quality Gates in this context are defined as points in the course of the development project when a decision is made on the release of the next project step on the basis of predefined quality criteria (Sondermann, 2007). The contents a team has to prepare for each Quality Gate as well as the outcomes are defined in advance. They are summarized in figure 5 and described in detail in the subsequent chapters.
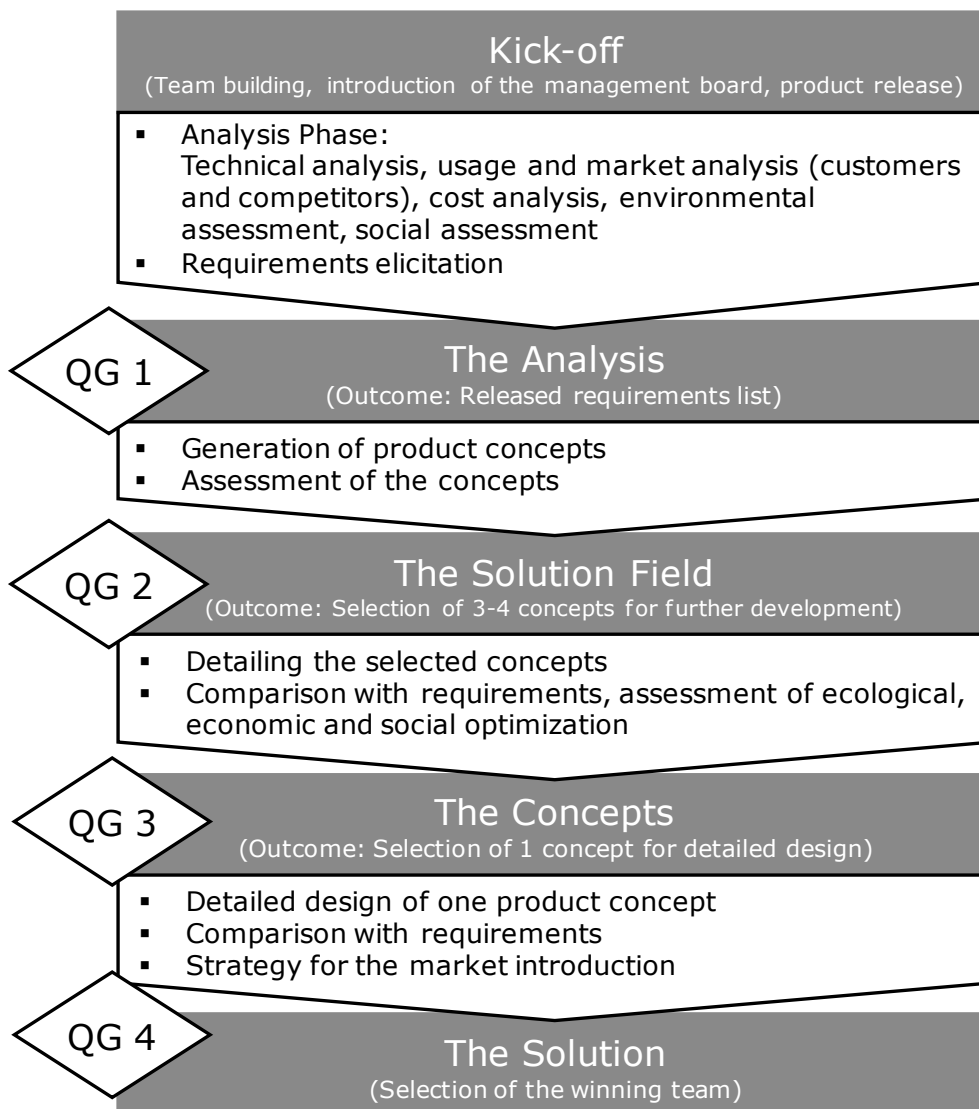
## Kick-off
(Team building, introduction of the management board, product release)

- Analysis Phase:
  Technical analysis, usage and market analysis (customers and competitors), cost analysis, environmental assessment, social assessment
- Requirements elicitation

## QG 1 — The Analysis
(Outcome: Released requirements list)

- Generation of product concepts
- Assessment of the concepts

## QG 2 — The Solution Field
(Outcome: Selection of 3-4 concepts for further development)

- Detailing the selected concepts
- Comparison with requirements, assessment of ecological, economic and social optimization

## QG 3 — The Concepts
(Outcome: Selection of 1 concept for detailed design)

- Detailed design of one product concept
- Comparison with requirements
- Strategy for the market introduction

## QG 4 — The Solution
(Selection of the winning team)

*Figure 5. The Quality Gates and working contents*

The teams present their results at a Quality Gate to the management board and give a recommendation on how to proceed. The final evaluation of the outcomes and decision on how to continue is carried out by the management. Evaluation criteria are hereby based on the development goals and sustainable business strategy defined by the management at the beginning of the tutorial. If the results of a team are not satisfying or no profound basis for a decision is available, teams have to repeat certain development steps and present their results in an unscheduled appointment.

### 3.1 Quality Gate 1: The Analysis

After the kick-off meeting the development teams have to carry out different analyses of the existing product regarding the optimization and the surrounding conditions. Beside a technical analysis, the market including its customers and competitors has to be analyzed. Also a cost analysis has to be carried out in order to identify the important cost drivers. For the environmental assessment, an abbreviated LCA (Eco-indicator 99) has to be carried out in order learn more about the ecological weak points of the products. For the social assessment of the product, so far only few findings and knowledge exists. It is not clear what distinguishes a socially sustainable product and which processes in the product creation process define this social sustainability (Hanusch and Birkhofer, 2010). But still a catalogue of social criteria based on the work of Hanusch (2011) is provided to the students, allowing the students to qualitatively assess the product concerning social aspects.

In the next step, the results of the analyses have to be interpreted and the focal points of activity need to be identified. Outcome of this analysis phase are aspects of the product the teams wants to optimize and a requirements list that needs to be released by the board of management in the first quality gate.

As for this first Quality Gate a lot of analyses have to be carried out, most of the time of the tutorial is provided between the Kick-off and the first Quality Gate.

### 3.2 Quality Gate 2: The solution field

Within the next phase of the tutorial the teams have to search for new partial solutions in the given fields that might improve the product. The teams compose the different partial solutions to product concepts and assess these solutions on the basis of the elicited requirements.

During the second Quality Gate the management board decides, which concepts or mixture of concepts out of the solution field have to be worked out in detail.

### 3.3 Quality Gate 3: The concepts

The 3-4 concepts selected in the second Quality Gate have to be further developed for the third Quality Gate. On the basis of the assessment of the ecological, economical and social optimization and a comparison with the requirements, the board of management selects the final concept.

### 3.4 Quality Gate 4: The solution

While in the previous quality gates each team gets individual appointments with the Executive Board, the final solution of each team is presented in Quality Gate 4 to all participants of the tutorial. Therefore, the teams complete and detail their selected concepts and give a detailed picture of it, especially showing the technical, economic, environmental and social improvements. In addition, a market strategy has to be created for the final concept.

Finally, after all the presentations and the Q&A-sessions of the management board, the winning team having developed the most convincing solution is announced by the management board.

### 3.5 Lecture series

In parallel to the tutorial, a lecture series "Sustainable Innovations – Development of sustainable Products (SusI)" is offered to the students in every winter semester. It is not mandatory for the students participating in the tutorial to also take part in the lecture series. But as students have the chance to discuss problems arising during the tutorial with the speakers of the lecture series, it is recommended to take part in this lecture series in parallel.

SusI is a lecture series with speakers from other institutes, faculties or universities as well as from companies and other external organizations presenting specific topics around the development of sustainable products.

The selection of speakers and topics changes each year but the contents are always adjusted to those of the tutorial. The lectures for example deal with the market for sustainable products and sustainability marketing, the assessment of environmental impacts or life cycle costing. With these specific lectures it is possible to support the students in the tutorial and to integrate the single speakers as kind of consultants into the role-play character of the tutorial. The schedule of the lecture series and the quality gates of the tutorial are depicted in figure 6.

At the end of the semester an oral examination is held in groups of two students and takes 30 to 45 minutes. The subject matter of the examination is based on the single lectures. However, the main objective is the common understanding of the overall topic "sustainable products" and the transfer and

cross-linking of the different lectures. The students receive 2 ECTS-points for the oral examination of this lecture series.

| Topic of lectures |
| --- |
| Sustainability |
| The market for sustainable products |
| Influence of user behavior |
| Life cycle assessment |
| Life cycle costing |
| Environmental law |
| EcoDesign |
| Product service systems |
| Sustainable production |
| Design for Recycling |
| Technology assessment |
| Examples from industry |

*Figure 6. Support of the tutorial by the lecture series*

## 4  EXAMINING AND GRADING

The grades of the tutorial do not result in a final written examination. Instead, the teachers assess the presentations of the teams, the project documentation as well as the working behavior of the team and the single students and this will be averaged to the final grade. The intention is to keep the workload for the students smaller and give them the chance to spend as much time as possible on the origin work.

The teams should prepare the project documentation in parallel to the origin work. This in addition supports the character of real work life of the tutorial. The documentation should contain the presentations, minutes of the team meetings and reports to the application of methods and tools as well as the created new product concepts. Ideally, the contents of the documentation are completed until the final quality gate and the teams just have to edit the single items.

## 5  TEACHING AIDS AND DOCUMENTS

For the support of the students' teams, the organizing institute provides different materials and working aids. Most of them are available as downloads from the internet:

- The method handbook is regarded as a basic support. It contains a collection of common design and specific EcoDesign methods. However, the students are not supposed to use all the given methods. Although a certain preliminary selection for the analysis phase exists, the students are free to choose their preferred methods and techniques for the creativity phase. Of course, basic methods as morphologic box or a technical and economical assessment should be part of the work.

- For each design step, the homepage of the organizing institute offers links to external software and tools, for example links to basic project management software, online-tools for surveys or environmental assessment tools.

- For the presentation to the board of management and for the final documentation, the teams have to use templates. The templates for the quality gates include information about the contents that have to be presented to the management. The teams face the challenge to present their results and ideas in a very short span of time (5 – 10 minutes, depending on the quality gate), but still the number of charts for the presentation is not restricted as the teams themselves decide how to present the contents to the board of management.

## 6 EVALUATION

In order to continuously improve the tutorial, an evaluation is carried out after every course. Herein, the students have the chance to evaluate the different aspects of the tutorial.

In figure 7 parts of the evaluation results of the course taking place in the winter semester 2011/2012 are shown.
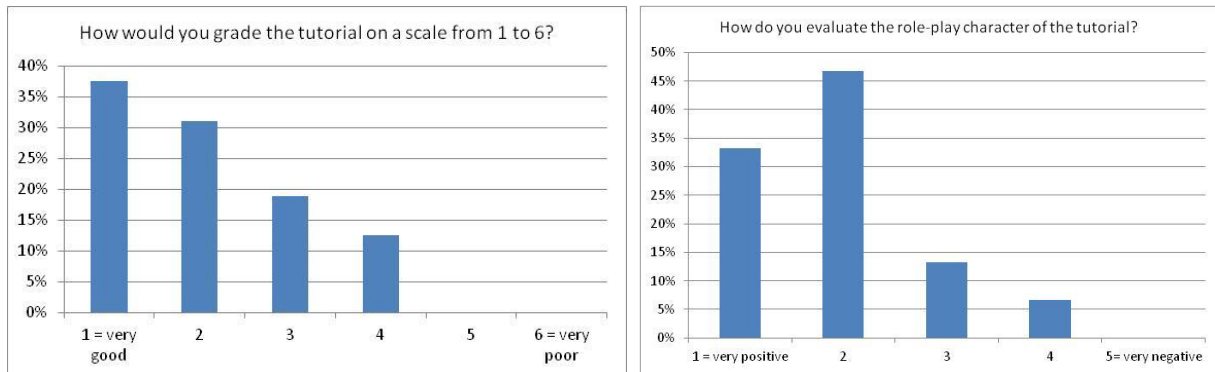


*Figure 7: Evaluation results of the Tutorial Sustainable Innovation (winter semester 2011/2012, n=16)*

This shows that the tutorial is in more than 35% of the cases graded with "very good" by the students. Additional 30% of the students judge the tutorial with "good".

Also, the role-play character of the tutorial is evaluated very positive or positive by more than 75% of the students.
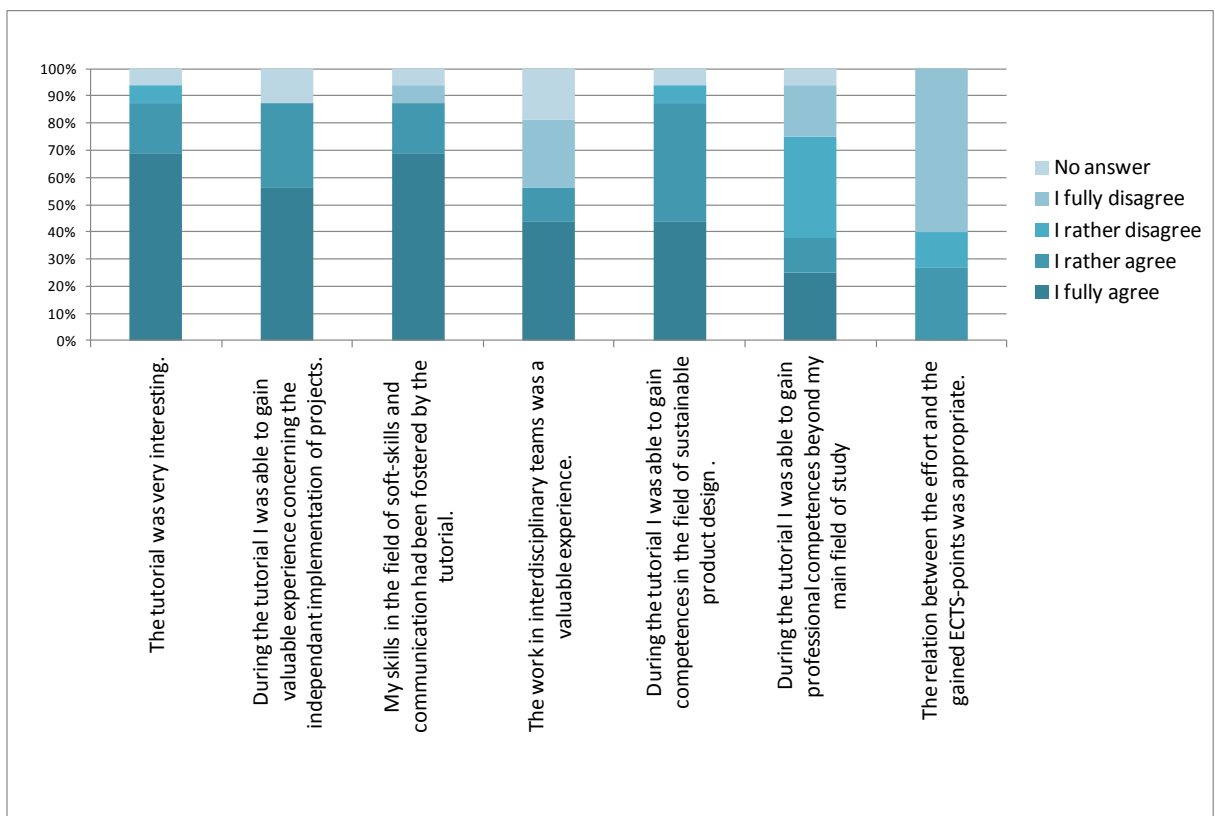


*Figure 8: Evaluation results of the Tutorial Sustainable Innovation (winter semester 2011/2012, n=16)*

Figure 8 shows that most of the objectives of the tutorial could be reached: most of the students fully agree or rather agree that valuable experiences in the field of independent implementation of projects could be gained, soft-skills and communication skills had been fostered and competences in the field of sustainable product design could be achieved.

Moreover, this evaluation also shows that the presented concept does not only provide benefits. Mainly criticized is the fact that the students have to incur much efforts for the course (see figure 8). Therefore, most of the students disagree that the relation between the time effort and the gained ECTS-

points is appropriate (at the moment the students gain 4 ECTS-points). As a result of this evaluation the organizing institute tried to keep the effort smaller for the students taking part at the current tutorial of the winter semester 2012/2013. This was realized for instance by giving more information to the students for the analysis phase, so that the work load for the first Quality Gate is kept smaller. Another option would be to increase the gained ECTS-points, whereas increasing the number of team members is not an option, as with teams of more than 6 members the coordination of the teamwork becomes more and more complex and would not lead to significant time-saving effects.

Moreover, the interdisciplinarity of the tutorial can be further increased. Here, the organizer plans to integrate an additional institute of a different faculty (e.g. from the field of social science) in the supervision of the tutorial. Thereby, more students of other disciplines could be acquired as participants for the tutorial (see chapter 2.2) and the teaching assistants of the different faculties could impart additional knowledge to the students in their field of research. Therefore the students would get more profound insights into other disciplines and scientific approaches.

## 7    OUTLOOK

It can be summed up that during the tutorial the students gain common understanding of sustainability and product development as well as subject-specific knowledge, e.g. environmental assessment and methodological competences. The role-play character of the tutorial with its Quality Gate-concept leads to conditions very similar to those in industry. The students not only learn how to present and defend their solutions but also train supplementing skills such as the ability for teamwork, self-organization and communication. The comparison of the students' results with those of subsequent industrial projects shows that the outcomes of the tutorial is of high quality and can represent daily industrial work.

Sustainability courses in the field of product design usually not deal with all three dimensions of sustainability: in most cases students have to design environmentally friendly products or have to implement EcoDesign aspects into design projects (see for instance Baeriswyl and Eppinger, 2011; Bernstein et al., 2011; Lloveras, 2011). Moreover, in some cases courses dealing with the integration of social aspects in design projects exist (see for instance de Vere at al., 2011; Garland et al., 2012). In contrast the TutSI integrates all sustainability aspects into the design process equally from the beginning.

As sustainable solutions often have to be defended in an intensive way a role-play seems to be the best possibility to learn all the aspects related to the development of sustainable products.

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