

# NEW INSIGHTS ON INDUSTRY DEVELOPMENT PROCESSES THROUGH ENGINEERING DESIGN STUDENTS' ANALYSIS

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## ABSTRACT

Traditional process models as described in the VDI2221, a standard by the Association of German Engineers, or the stage-gate system by Cooper are well known and applied in many engineering companies. Other models such as integrated engineering, agile project management and design thinking have been developed to find more efficient and effective approaches. Their grade of application in industry, especially in mechanical engineering is rising – often beginning in pilot projects. The influence of these and other approaches are reflected in an engineering course and by carrying out a survey. The survey itself helps students to deepen their process knowledge and supports them by analysing and assessing the company they work for.

Suggestions and examples for education in engineering design processes are derived from latest findings and developments, industrial, educational, sustainable and social influences but also recent research papers. A broader learning of engineering processes, transfer of knowledge concerning alternative or integrative processes and socio-cultural aspects are suggested.

*Keywords: educational concept, engineering design and development processes, educational suggestions on processes, process model, survey on engineering processes*

## 1 INTRODUCTION

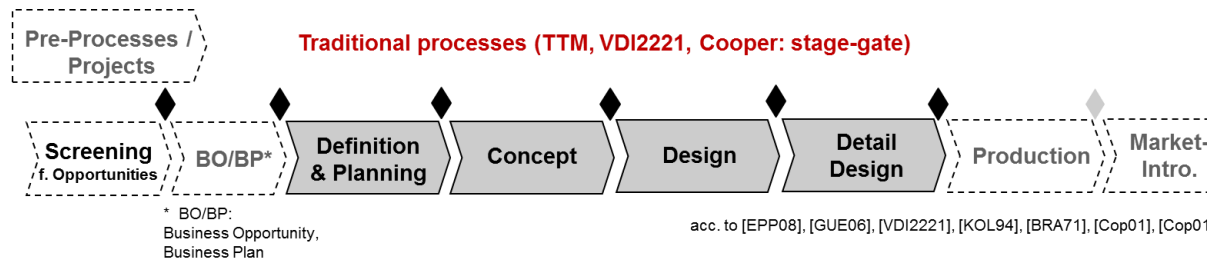
At the DHBW Cooperative State University engineering design students are encountered with a course on systematic approaches, processes (e.g. time to market process, integrated engineering processes) and methods of several kinds to facilitate and strengthen efficiency in engineering design and development. A survey has been carried out in six Bachelor courses and a Master course, in which altogether 210 students were enrolled. The study evaluates among the student's which education concept helps to broaden systematic and methodical approaches best, which process models are found to be applied in industry, thus applied in the student's own company. The latter point can be analysed as every student at the DHBW cooperative university has a contract with a company and spends half of the studies in the company, spending more or less alternating three months at university and three months in the company per semester. This allows insights into a high number of companies of different branches and sizes (approx. 120), contributing to this study on finding important insights in design and development processes in the companies. Suggestions are derived from education experience and the survey analysing application in industry.

## 2 LECTURE CONTENTS, CONCEPT AND COURSE DETAILS

The lecture "Engineering Design and Development" consists of 24 hours of lecture time distributed over 11 weeks. In week twelve a written exam takes place where the lecture contents are tested. Some of the lectures consist of the traditional way of "teacher-centred" teaching, especially on processes, investigative and empiric methods. But especially creativity methods are applied in exercises and group work. This allows students to experience the methods. Insights to the lecture concept on methods and an evaluation by the students have been presented on last year's conference [1].

The traditional way of design and development processing (VDI2221 [2] and Cooper's stage-gate system [3]) was taught in a teacher-centred lecture. The alternative processes (agile project management,

design thinking and business model innovation) or integrative processes (open innovation and life cycle management and sustainable engineering) were described by their main objectives and philosophies, figure 1. Additional information was given then in blended learning on the e-learning platform.



#### Integrative and alternative processes and models:

- **Integrated PDD**  
(multidisciplinary teams, process orientation, customer integration)
- **Agile Project Management / Scrum**
- **Design Thinking**
- **Open Innovation / Crowd Sourcing**
- **Business Model Innovation**
- **Life cycle management and sustainable engineering**

Figure 1. Process Models and Approaches in Product Design and Development (PDD) [4]

The lecture also includes a group work task on processes. The group work allows the students to team-up, choose a free problem in the group and work their way through a development process. In a down scaled way the groups work their way through the first two to three typical design and development process phases, from problem definition to the concept phase and design phase. Optionally the groups can also choose the management process system: The traditional development process according to VDI2221 [2] or stage-gate system by Cooper [3], alternatively agile process management, design thinking or if applicable business model innovation. The requirements given to solve their design and development problem was to set up a user/ customer requirement list (specification sheet), a small market research to address the market need, performing of minimum two creativity methods, assessment of the found ideas and a sketch or prototype of the concept to solve the problem. Prototyping was addressed to be desirable but not a “must”-requirement. The groups were asked to present their results in a five to ten-minute presentation to the class. A documentation of the results was asked to be uploaded in the e-learning platform. The task was set free but allowed to setup a small project, work through it systematically in a team and allowed to set the methods and processing into a competitive context [1].

In every class at least one group chose one of the alternative processes, so that each course could participate of group work experience on e.g. design thinking or agile process management along with the traditional processes that have been taught [1].

Life cycle management and sustainable engineering was introduced to sensitise the students of addressing sustainability, environmental and socio-cultural requirements, especially in the early stages of engineering design and development. The tables given in the E&PDE paper by T. Empson on the United Nations Planetary Boundaries and sustainable development goals for 2030 are presented in the lecture and uploaded to the e-learning platform [5], [6]. The effect could be observed in the group work presentations as quite a few groups addressed sustainability requirements.

### 3 CONTEXT AND OBJECTIVE OF THE SURVEY

As the students learned about processes, alternative and integrative processes they then were asked to take part in a survey on processes. In the survey they were asked to point out which processes are conducted in the company they work for and to estimate to which extent the processes are applied. The objective of the survey is to validate if alternative processes, as learned in the lecture, are performed in industry and to observe trends or a shift to other process models. Though the numbers can only be a first estimation, tendencies can be visualised – and can be a basis for following classes and years to come.

The survey was carried out in six courses, five Bachelor courses of different years and a Master course, in which altogether 210 students were enrolled. The survey was carried out by 127 students which sums up to a participation in average of 60%. Two courses were asked to take part on the survey directly in class which resulted in a participation of 92% and 82%, while the other courses were asked to fill out the survey digital which resulted in a low participation of 25% in one course and in the other courses between 55% and 65%. The questionnaire was setup and distributed to the students that have attended the course continuously. The questionnaire consisted of 10 questions, starting off with questions concerning the context, e.g. students partner company (size, systematic and structural setup) and the application of processes (traditional processes like stage-gate System [2], [3], alternative management processes, like Design Thinking or Agile process management), but also concerning multidisciplinary and voluntary team building provision within the company.

The objective of the survey can be concluded to the following points:

- Clarification of student's context (company size, grade of multidisciplinary teamwork, organisational evaluation).
- Reflection on processes and process models learned in lecture and their application in industry.
- Which processes are applied to which extent in the partner companies?
- Evaluation of importance of methodical and systematic approaches / mind-set of students.

#### 4 RESULTS OF THE SURVEY

Most of the students (41%) work in companies with more than 5000 employees and 94 percent of students answered that their company works in multidisciplinary teams. 61% of the students thought that their company processes are structured and defined, 36% thought of the processes only being partly structured and defined and only 3% answered that processes are not structured and defined, figure 2.

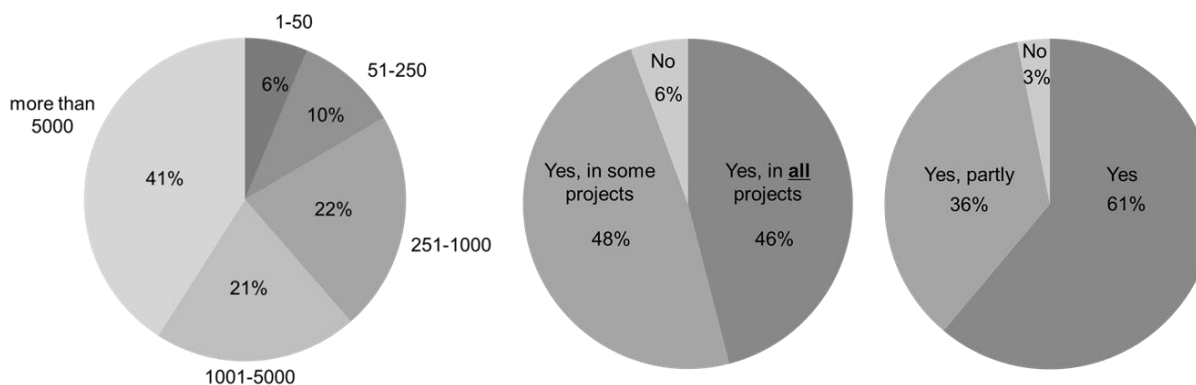


Figure 2. Company Sizes, grade of multidisciplinary and evaluation on process orientation

The survey then clarifies how many companies use the traditional development processes according to VDI2221 [2] or stage-gate system [3] and to which extent other alternative or integrative processes or process models are applied, table 1.

The results from table 1 can be summarized:

- 70% of the companies use the traditional processes with 50% of those companies to a degree of more than 70% in their projects. Traditional processes are still “state of the art”.
- Customer and user integration are realised in 90% of the companies, in 60% of those to an extent of more than 70%.
- 30 to 40% of the companies use alternative process management systems, such as Open Innovation, Agile Project Management (e.g. Scrum) and Design Thinking, in majority to an extent of less than 30%. The percentage of students that answered that these alternative processes are not applied or unknown or miss on information is rather high and therefore not counted (column “not applied” or “no answer”).
- Multidisciplinary teams in 70% of companies consist of minimum three disciplines, each with a 70% to 80% workload.
- 50% of the companies consider employee-initiated projects.

- Other process models are not widely used. Examples that were quoted are either quality or production processes or only methods. Moreover, a high percentage of 90% of students did not report on other process models.
- The curves in the diagrams show the trend (polynomial, 4<sup>th</sup> grade).

Table 1. Processes and grade of application in companies

applied in %:		80-100%	70-80%	50-70%	30-50%	under 30%	not applied	no answer %
traditional processing (stage gate, TTM, VDI2221)	30 20 10 0	26	28	22	13	10	1	31
customer/ user integration	30 20 10 0	26	34	16	11	12	2	11
open innovation	30 20 10 0	7	18	20	18	23	14	56
agile processing (e.g. Scrum)	30 20 10 0	5	8	14	15	34	24	38
design thinking	30 20 10 0	7	15	22	22	24	11	57
multidisciplinary teams * min. three disciplines, each with 70 to 80% working time	30 20 10 0	12	25	23	20	19	1	27
own initiated projects	30 20 10 0	3	20	19	20	31	8	41
other process models	30 20 10 0	8	15	23	15	8	31	90

The survey finally asks students to evaluate on the importance of methodical knowledge and systematic approaches in engineering. From a grading system from 1: not relevant to 5: very important the students evaluated as follows on the last two questions:

- How important is methodical knowledge for engineers?  
grade 4.2 with an average deviation of 0.8
- How important is a systematic approach (e.g. through processes) in engineering?  
grade 4.6 with an average deviation of 0.6

## 5 SUMMARIES

Emerging processes (compare figure 1) and methods are finding continuously more application in industry. The challenge of educators is to keep track, integrate increasing content in their programmes and innovate educational concepts. A mix in the educational concept activates student's learning approaches and supports learning success:

- traditional learning (teacher centred learning),
- student centred learning (experience through exercises, team or group work, reflective possibilities and self-assessed prototyping which delivers direct feedback) [1],
- e-learning – and as this paper proposes: the setup of surveys which link lecture experience with practical reflections.

The survey shows that engineering students have gained knowledge over a wide range of processes in the lecture and that they agree on methodical and systematic engineering being very important. The lecture and fellow students profit of already existing process and project management knowledge because DHBW students have already experience through strong involvement in their partner companies (50% of study programme). Each course could participate of group work experience on e.g. design thinking or agile process management, approximately 10 to 20% of the groups, along with the traditional processes that have been taught and experienced. The survey shows that according to the student's

analysis most companies still build on traditional / classic processes (70%-80%), such as stage gate system or time to market processes. Alternative processes and process models (agile processes, design thinking, open innovation) are gaining on application (30% to 40%), but in majority on a pilot project basis (majority of companies to less than 30%).

## **6 CONCLUSIONS**

The results of the survey lead to discussion and first reflections. Of course – and this may be worthwhile an additional analysis – some questions are open for interpretation, e.g. ‘customer integration’, ‘multi-disciplinary teams’, and moreover it will be hard to define percentages of application in a company precisely. This is in fact the challenge: The students have learned about the integrative and alternative processes and will majorly know the definitions, when and how to apply them – being the objective of the lecture. Surely, they will have difficulties to estimate the percentage of application in their company. It may seem obvious to directly ask experts in the companies, which results in a comparative survey. The challenge is that experts in industry may not be aware of the alternative and integrative process definitions – some sort of a definition will have to be “delivered”. The estimation of the percentages of application will be – in comparison to the students – more precise. A comparative survey interviewing experts in industry may lead to a more comprehensive picture.

Nevertheless, the results lead to the conclusion that alternative and integrative processes are being applied in industry – in some to a rather high extent. Therefore education should address that there are alternatives to traditional processes and integrative processes, too. Optionally traditional processes can integrate alternative, agile and innovative processes and process models due to the project circumstances. Experience in systematics, methods and processes – also alternative and integrative processes (open innovation, life cycle management) – are therefore essential for an overall picture in engineering.

## **7 OUTLOOK**

The survey is an educational tool itself. The theory on engineering design processes is reflected by the students in the survey as they are asked to assess their companies. Trends can be evaluated, especially when the survey is carried out regularly in following courses – maybe even in a more comprehensive way as reflected in the conclusion. The partly high number of students not evaluating on certain questions should be analysed in more detail. Most probably there are some students that are not aware of the asked process(es) (lack of depth of knowledge) and of course it may be difficult to estimate percentages on application, e.g. not knowing if the company applies a rather exceptional or specific process. To overcome this knowledge gap more process knowledge should be addressed by additional e-learning concepts (presence lecture time is limited – not all process models can be experienced).

Life cycle management and sustainability should be addressed in lectures: As observed, addressing ‘sustainability’ leads students to apply sustainability criteria in their group work.

Methods and systematic approaches in early stages of design and development are essential. – Success in application is fostered when students are asked to apply and experience these in teamwork [1]. Study programs can be successful by addressing employability (business demands) through a high grade of practical experience, reflective views on theory and application in business, but also addressing socio-cultural demands [7] – some concepts can be derived from this and former papers.

In the next step, the survey will be also carried out with experts in industry. A comparison of the results with those of the students shall be analysed. The objective is to observe trends, foster knowledge transfer and evaluate educational gains from the student’s analysis about the lecture concept and changes. The comparative survey with experts can help to get more insights in both areas: on the student’s perspective and insights on industry dynamics in processing.

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