DESIGN METHODS — WHAT REACHES INDUSTRIAL PRACTICE?

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Industry promotes the use of design methods. In the everyday work of designers, methods as they are taught at university are not applied as expected. One reason seems to be a deficit in terms of knowledge for selecting and adapting a particular method to a given task and situation and reflecting the use afterwards. The integration of methods into the companies' process and documentation system is essential. One central and simple design method for successful projects has proved an open and serious culture of design reviews.

Keywords: Design methods, industrial practice, adaption of methods, design reviews.

1. INTRODUCTION

The use of design methods as well as the systematical approach when performing a design project is regarded as a precondition for successful product development. It is common sense that the complex tasks of designers require efficient support [1, 2].

Existing methods developed in a science community and taught at university aim to support designers efficiently [1]. Nevertheless, in practice design methods suffer from acceptance problems [3–7]. Engineers in practice seldom see the success of good design solutions as a successful application of design methods. On the contrary: many engineers decline not only the opportunities to improve their methodical skills, they even doubt that methods can lead to a better result. Methods have the preconception of being cumbersome and time consuming [5, 6]. This skepticism, and preconceptions have to be taken into account when developing, teaching and promoting design methods.

This paper presents a critical reflection on the use of design methods in practice. Examples are taken from the authors experience in industry. Whereas the personal and subjective observations stem from a particular company, they seem to be transferable to others [6].

1.1. Personal background

The author has been working as a design and development engineer for Heidelberger Druckmaschinen AG since 2001. Prior to this, he graduated from Darmstadt University of Technology. As a PhD student, he was member of a design research project and gave lectures for electrical engineers in systematic design. Thus the authors' qualifications in design methodology can be termed as comprehensive. Furthermore he was already an enthusiastic designer and was eager to apply design methods. After many years at the university, he was interested to see, whether he would be able to apply all his theoretical skills for designing products on a commercial basis.

During the last 9 years the author has experienced many facets of engineering design within an industrial environment, e.g. designing many different kinds of parts and mechatronic systems, applying methods explicitly with colleagues and students, working continuously as part of a team with very

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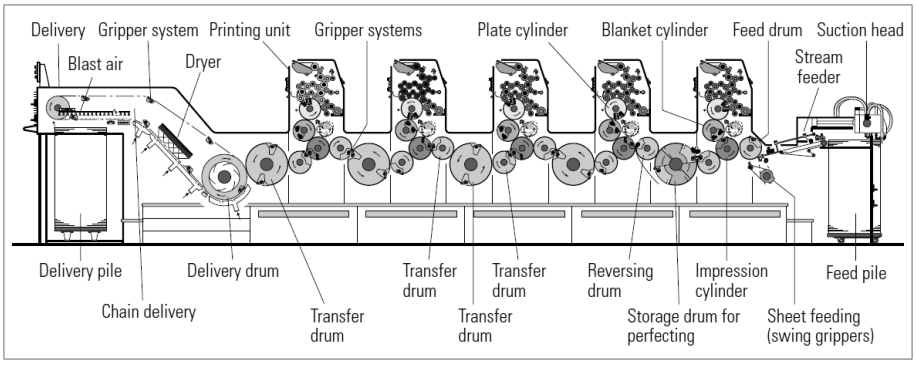

Figure 1. Sheet conveyance in a sheet-fed offset press [8].

differing engineering characters, managing several design projects and a design department, and last but not least enjoying several successful market launches of "his" products.

1.2. The company and its products

Heidelberger Druckmaschinen AG is a company that produces solutions for the print media industry mainly sheet-fed offset presses. About 16000 people are employed in several German and one Chinese factory as well as in sales and service units worldwide. In the central R&D department in Heidelberg, Germany, approximately 1200 employees design mechanics, electronics and software. *Heidelberg* is market leader with a market share of approx. 40% worldwide and an export share of approx. 85%. Offset presses are items of capital expenditure. Main features being high precision, reliability and automation.

2. SYSTEMATIC DESIGN PROCESS AND DESIGN METHODS IN THE COMPANY

Systematic design and design methods are strongly recommended by the management of the Heidelberger Druckmaschinen AG. With the following programs, employees are encouraged to apply methods.

2.1. Process for solving problems systematically

Several years ago all employees — from CEO, to engineers, workers, drivers and porters — were taught in a so called Heidelberg Quality Management (HQM) program for at least two days. Therein client orientation, client satisfaction, a systematic process for solving problems (see Figure 2) and the

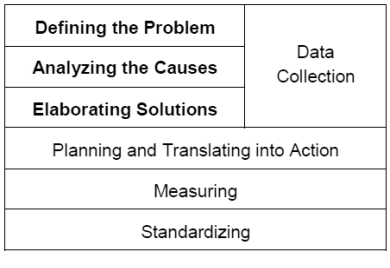

Figure 2. Systematic process for solving problems. *Source*: Heidelberger Druckmaschinen AG.

advantage of actual teamwork played central roles. Internal trainer teams instructed groups of about 20 people. As the title suggests, the generic aim was to increase product quality by working together and achieving a common understanding on how to solve the right problems efficiently.

The overall image of this program in the R&D department was not solely positive. The reason might be that designers easily see through, when common sense wrapped into abstract terms comes along as a method. A company, which undertakes such a huge effort, becomes suspect for many employees. In this environment a teacher who wants to promote methods convincingly must be very sensitive to such scepticism and has to highlight it as a central subject. This is much more relevant with experienced engineers than with students (see paragraph 3.2).

Figure 2 shows the systematic process for problem solving as it was taught in the HQM program. This looks banal. In fact in practice the first three even more banal points "defining, analyzing and elaborating" prove very useful in everyday work. It often happens that the actual problem becomes hidden behind nice solutions.

It is human that designers fall in love with their own ideas and forget the actual problem to solve [5, 6]. Two simple questions (What is the problem? What are the causes?) have turned out to be a very quick and efficient "method" to overcome the temptation of diving into the most attractive sub-problem. This temptation can be observed not only with "P-designers" [5] which have no education in methodology but also with designers keen to apply their comprehensive methodical skills. For this reason the depiction in Figure 2 could be even simpler since the decisive parts are the three bold terms.

2.2. Internal Design Guideline

On each desk in the R&D department of the mentioned company there is a booklet 72 pages long with an internal design guideline. This describes the design process as it is controlled by the management. The main focus lies on the so called milestones of the product development process and the quality gates of a product life cycle (see Figure 3).

The Quality Gates are reviewed for each design project by its steering committee. In every design project Quality Gates and Milestones are respected as the main guide line — since this is demanded by the management. This demand seems to be helpful and perhaps necessary for the appliance of design methods in a company — not simply because of the influence of authority. The authors' observations lead to the conclusion, that the full integration of a particular method into the companies' process and documentation systems is a precondition for an efficient use of this method. Probably even more important: This integration proved to be necessary to give designers *the impression* not to waste time

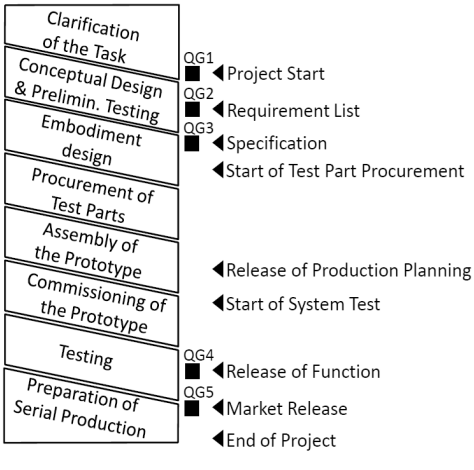

Figure 3. Quality Gates ■ and Milestones ▲ in Design Projects at Heidelberger Druckmaschinen AG.

with the use of methods. And this seems to be *the* crucial point for the success of design methods in practice [5, 6].

2.3. Internal courses for design methods

As part of the companies' internal education program, courses in design methods are offered. Trainers are sometimes external but often recruited from the staff. Courses available are e.g. Clarification of the task; QFD; House of Quality; Techniques for creativity like brainstorming, method 635 and TRIZ; evaluation methods; FMEA; RiskMan, Design of Experiments (DoE).

2.4. Qualification engineers

One new approach for improving the procedures within the R&D department is the creation of a department of qualification. The main aim is to qualify new products. Additionally, engineers in this department support design projects. They are part of the project team and supervise the project team in terms of proceeding systematically and using methods. The success of these colleagues depends on their methodical and even more on their social and psychological skills. The first attempts are encouraging.

A new guideline for design reviews was worked out within this department. This guideline seems to be easy to use, flexible and useful. It is described and assessed in paragraph 3.3.

2.5. Initiative for improving collaboration within the R&D department

After an intensive review by a consultant company a huge initiative called "BiRD" (Best in R&D) was started in 2008. The aim is to improve the results of research and design by developing a positive, open and confident attitude to work. The five basic principles are "working committedly", "developing economically", "increasing reliability", "communicating actively" and "overcoming limits". These basic principles form the roof upon organizational columns like strategy, efficient processes, product standardization, multi project management, etc.

From time to time all teams present their ideas for improvements of the daily work in so called "market places". Best practices are presented to all colleagues. In a big R&D department like the one at Heidelberger Druckmaschinen AG, this is a very good panel for exchange among designers, especially among colleagues who have no close contact in their daily routine. The experience with this initiative looks promising. Similarly as described in paragraph 2.1 the effort the company puts into this initiative seems to make many employees sceptical. For the organization it is difficult but important to deal with this. A lot of effort is necessary to find simple and convincing ways to fill the staff with enthusiasm for improving their own as well as the company's design procedure.

3. OBSERVATIONS WHEN USING DESIGN METHODS IN PRACTICE

Despite similar references [4–6] the author is disappointed how seldom and poorly design methods are used by himself and his engineering colleagues. This confirms the thesis that "engineers decrease their methodical skills rapidly when they commence design work in industry" [11]. At university as lecturer and supervisor, the author promoted design methods since he was convinced of their benefit. Now in "real business" he sees difficulties he never imagined before.

In the following four examples of using methods in the authors department are described and analyzed.

3.1. TRIZ-Workshop

Starting as designer for the feeder of offset presses, the author found the documentation of a recently performed TRIZ-workshop on "how to increase performance feeding sheets of paper into an offset printing press" in a 51 page booklet. 13 experienced and motivated engineers performed a 3 days'

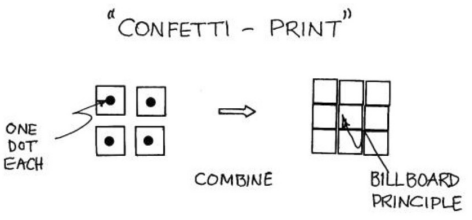

Figure 4. The Confetti concept from the TRIZ workshop. *Source*: Workshop Documentation.

workshop on this subject. The two main aspects were increasing speed and reliability. The workshop was moderated by two actual TRIZ experts from a US partner company at that time. All participants are still enthusiastic when remembering this workshop. In small groups with changing composition 155 concepts for a so called "feeder" were generated.

Analyzing the 155 "concepts" a huge variety in terms of extent and abstraction can be discovered. E.g. one of these concepts is the idea not to print an entire image on a sheet but printing dots on very small paper particles and subsequently combining these colored confetti to an image (see Figure 4). Another "concept" is not to print on rectangular sheets but on round ones. Many other concepts describe the state of the art such as adjusting sheets during movement, deformation of the sheet to make it stiff in the transport direction or using suckers that elevate *and* transport the sheet.

Despite many reservations on the workshop results, the comprehensive collection of ideas is used frequently when looking for development projects that look beyond the usual horizon. There is still the hope that this wide collection can inspire the development of feeders one day. Unfortunately it hasn't done so far.

On asking the participants about their main impressions, the answers were: fun, great expenditure and absurd results. Three TRIZ-workshops on other problems were performed in the company with similar results as far as acceptance is concerned. A software tool was purchased, that supports TRIZ, but it hasn't been applied seriously so far. The matrix of inconsistencies has been on the author's desk for 3 years since his training for the TRIZ-software. He was eager to apply this but he never did. Obviously, the subjective attraction of the actual benefit was never big enough to surmount the level of abstraction and complexity that is inherent even in this small part of the method.

Of course TRIZ is an extreme example in terms of expenditure. The moderation and preparation is considered as important and in the particular case both seem to have been very good. Nevertheless, the workshop in 2001 shows typical problems for the appliance of complex methods:

Once it was decided to perform a TRIZ workshop, it was done, because one wanted to find really new solutions for the feeding. By organizing the session with consultants from the US it became inflexible in some aspects. All questions were treated in the workshop — which is not to be criticized as itself. But in retrospect it would have been useful to take the time to continuously analyze the procedure. Since this did not happen as intensively as it would have been necessary, the participants could not see for which problem the method was actually appropriate and for which problem not. Therefore the overall impression of the participants was that this method is costly and too many results are either well known or nonsense.

This observation is not a judgment on the method but it shows how difficult it is to apply methods in a convincing manner. Post project learning in connection with using design methods is too often missed at university and even more in practice. The subjectively regarded time pressure of a designer in industry makes such a necessary reflection very hard to perform [9]. At the end this deficit is jointly responsible for superficially negative image of a particular method and of design methods in general especially for experienced engineers in industry. The author comes to the claim, designers need the personal experience that methods help to accelerate the design process *and* help to come up with better solutions. For this an efficient tool for selecting methods is required [7] but also an honest reflection after the use of a method.

3.2. Design of Experiments (DoE)

As one example for a method, recommended by the management "Design of Experiments" (DoE) is described in the following: Developing offset printing machines to a high standard requires lots of experiments. Since the extent of large experiment series very often exceeds the individual time budget, DoE, a method for statistical planning and analyzing of experiments, was identified as a useful tool. It helps to reduce the number of necessary experiments considerably. Dependencies between process-parameters can be calculated later on. Therefore a crucial part of this method is to design a statistically calculated plan for the experiments.

To perform a useful DoE extensive experience is required. In addition the necessary software tool must be mastered. Therefore some key users are trained to advise others when planning test series with the DoE-method. Despite the obvious benefit, the complexity of this method is a considerable hurdle. Experience has shown that in retrospect one frequently recognizes the preconditions for DoE were not met despite the fact that they were considered during preparation. Such experiences are contra productive as far as the promotion of this method is concerned. On one hand it proved to be important to provide a strong means to select a suitable method [7]. On the other hand it seems to be even more important to teach the awareness of the characteristics and the preconditions together with the method itself [10]. The author made the experience that discussions about the usefulness of the method in retrospect are esseintial in order to give confidence to designers in terms of applying a particular method in their daily work.

3.3. Design projects with students

In several projects with students who performed their practical training or diploma theses within the company, design methods played a central role. It became obvious, that there is a decisive difference between students and design engineers with responsibility as far as trust in methods is concerned. As it is mentioned in [10], students seem not only to rely on the use of methods; they often even think design methods automatically lead to good results. It is fun to observe how naively they use the tools they recently have learned at university. On the other hand it seems to be very difficult for them to reflect critically on their use of methods.

Another weak but interesting aspect is that one does not dare to invite experienced colleagues for a design session with students, when the students want to apply a method. Of course there are colleagues who are interested in new approaches. But there are more colleagues — and these are often the talented ones — who have reservations that make it difficult, if not impossible, to actually motivate them for a workshop with a particular design method. These method declining designers hold the strong conviction, that methods do not help them to come to better solutions but that methods are time consuming and help weak inventors to hide their weakness. It is not clear, whether it is possible to prove the superiority of design methods compared with an intuitive trial and error procedure [4, 12]. In this context the examples used when teaching design methods can play an important role: First of all, they have to be realistic [7]. This requires a huge effort for every teacher, since examples have to be adapted to the audience. For students this might be achievable. For experienced designers a convincing teacher probably must take examples close to their own experience. If necessary, a concrete method has to be flexibly adapted to a given task, situation and engineering team [3].

3.4. Design reviews

The previous paragraphs could lead to the conclusion that all designers observed are ignorant in terms of methods and most existing design methods are too complex and academic. This is not the case. There are some "methods" which are widely accepted. First of all there is the "method" design review [6]. Successfully performed design reviews have been perceived by the author in all decisive situations of a project. Recently, design reviews became part of any design project in the company. They are explicitly demanded by the steering committee. A review guideline is available that helps to prepare and structure 9 possible types of design reviews in all stages of a design process. The guideline advises

the invitation of 5–7 participants and it makes suggestions from which parts of the company they should come.

Design reviews proved to be very useful in informing one another, and through this in strengthening mutual confidence as well as to developing team spirit [6]. This is important since within such a review the particular designer should not show how great his solution is. The designers are encouraged to show the weak points to their colleagues. The main aim of a review is to bring solutions up for discussion in order to detect and to eliminate the weak points as early as possible. Therefore the composition of the review team is decisive [6]. Till now, the main principle for recruiting the right people for a design review is knowledge to solve the problem. Such reviews provide the framework to collect specific experiences and opinions of others in a structured way. It is the panel where different generations of designers do learn from each other. Already approved solutions (parts and principles) which are useful for the discussed solutions can be identified and reused. Thereby the responsibility is split and the decision for a particular solution is accepted by the whole team.

The management is convinced decisions worked out in such reviews usually are better than founding the decision on a sophisticated evaluation method in any team. Projects with an open communication atmosphere and a lively unbureaucratic review culture are seen to be faster and easier in series production launch.

Last but not least struggling together for the best solution is fun! One decisive basis of this fun is a clear and efficient communication during reviews. In this context, experiences with drawings on the table proved to be very good. Drawings on which every participant can scribble can't be substituted by 3D CAD models projected to the wall by a beamer. Paper does not disappear. Both techniques can complement one another but the drawing on paper usually proved more significant for a fruitful discussion.

4. CONCLUSIONS

Methods aiming to support designers in industry must be easy to use [2, 4–6, 10, 11, 13]. In a short time with little effort the method must help the designer to come to a solution that is better in comparison to solutions he usually achieves without methodical support [5]. If these preconditions are met, designers will have fun and they will enjoy using the method, something that is widely underestimated.

For teaching and promoting design methods, realistic examples are essential [4]. In design classes designers have to make positive personal experiences with the use of a particular method. Therefore the training of the flexible adaption of the concrete method is important [9, 10] as well as routine in the reflection of the design process and the use of methods in retrospect. In addition, teaching design methods has to include the awareness of the characteristics and preconditions of each single method [10].

The organization must support the use of design methods by the explicit demand of the management. The use of the method must be fully integrated into the company's documentation system. Experts must be available to advise engineers with less experience in selecting a suitable method and applying it. The company must supply an easy to handle means to select the suitable method according to the problem at hand, situation, team and available time [6].

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