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Understanding Design Methods - Using Explanatory Videos for Knowledge Transfer in Engineering Disciplines

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The application of design methods in engineering practice is improvable, although the use of methods is often seen as helpful and even profitable with regard to process efficiency and effectiveness. The main barriers cited to apply design methods in practice are the theoretical descriptions and the complexity of methods. Thus, this paper focuses on new media to provide method knowledge in order to overcome the above mentioned barriers. The approach presented is based on method videos to explain the aim and application of methods.

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1. Motivation

Considering the fact that knowledge generation, validation, and documentation are decisive aspects of product development, efficient knowledge handling throughout the entire product development process becomes a key role. Thus, systematic approaches within the design process will become increasingly important. Development and innovation management provide various methods to support the product development processes (PDP). The term “method” is often understood as a rule-based planned sequence of activities [1]. So far, some methods have been widely used in companies, but most methods are rarely known and thus only used to a restricted extent [2]. The reasons for a poor application in practice are, e.g., the lack of know-how regarding an effective integration into the product development process [3] or the missing adaption possibilities of methods to the company's situation, e.g. [4]. Hence, a demand and situation-specific supply of design methods in practice should be an important objective of methods research. Therefore, the preparation and tailor-made provision becomes a key role in the transfer of methods from research to practice [5].

2. State of the Art

2.1. Design Methods in Practice

Methods describe a goal-oriented procedure. Thus, they have a descriptive and instructional character and should support the user to achieve a certain goal. However, the outcome of the application of a method is open [1][6]. For instance, Lindemann [1] defines the term "method" as the description of a rule-based and planned action to perform certain activities according to its specification. Thus, methods provide a step by step procedure to solve a specific problem. A method can include the use of different tools in order to achieve the goal. They can comprise guidelines which tools should be used as well as the order in which they should be applied. Due to the diversified work within product development, numerous methods for different goals have been developed such as analysis method, idea generation/solution finding methods, evaluation methods and cost and economic methods.
In general, these methods use experiences already gained to solve repeating problem patterns. This refers not only to the support of the engineer and the management, but also to the

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support of facilitating organization, planning, and concept development [6][7]. Despite the wide range of support, methods have been insufficiently integrated into daily development practice so far and even in this context, have only rarely fully exploited in their potential [8]. Franke et al. [9] find that successful firms use methods during PDP more frequently. These methods are not only used in the idea phase but also during the conceptual design and later stages of the PDP. Yeh et al. [10] show that methods appear to be effective although engineers use them rarely in practice. By analyzing more than 400 development projects from practice, Graner [5] showed that an integrated method application can strongly support the engineer in the product development process. In these projects, the intensive method use was correlated to the success of the new product. In practice, however, methods are not regularly used and only a few of them are accepted [6][11]. Recent research on this lack of acceptance concludes that science is often too far away from reality, e.g. [12][13]. The individual needs abilities of the engineer as well as individual working, and thinking patterns have been taken into insufficient consideration [4]. In addition, the verifiability of improved results and decreased development effort due to the method application can only be revealed to a limited extent, meaning under specific conditions. Furthermore, there is mainly a missing expertise about how methods can be appropriately integrated into the PDP [14]. Another reason mentioned for criticism is that methods are often complex and theoretically described [2].

Two independently conducted studies on the methods application in practice showed that analysis, creativity, and evaluation methods are most applied in practice [15] and [16]. The focus of both studies laid on the use of methods along real ongoing product development processes. The additional finding was that, for example, creativity methods are used not only during the idea generation but also for the support of profile detection and modeling of principle solution and embodiment. Both studies show independently of one another that only a small number of methods is used in practice. Bavendiek et al. [16] report 4 to 5 methods on average being applied at least rarely. Albers [15] finds a small number of selected methods within a method category. For example, almost every engineer (98 %) uses brainstorming in the field of creativity methods, while other methods such as 6-3-5 (42 %) or brain writing (36 %) are less than half as often used. Regarding the evaluation of the suitability of methods, it is conspicuous that even the methods used infrequently are considered as successful. For instance, brainstorming, as one of the creativity methods, was by far the most frequently stated method, whereas the suitability of other creativity methods was evaluated constantly well. The results show that the variety of methods developed in the past and hence the subsequent potential is not yet sufficiently exploited in practice. Many designers see no improvement by using methods. Most of them are of the opinion that without the use of methods just as good results as without can be achieved in even less time. Thus, it happens rarely that an engineer independently accesses methods [15].

2.2. How to increase the Acceptance of Design Methods?

To meet the above mentioned problems of methods within industry projects, various approaches have been presented. Geis et al. [3] propose a method transfer framework which consists of four pillars (simplification, adaption, promotion and training of methods) as well as of the basis of daily routine in industry, knowledge of designers and experience in science. These aspects contribute to a better acceptance and successful usage of methods in industry [3]. Stetter and Lindemann [8] developed another transfer model for methods consisting of five steps from the initiation of a method implementation process up to the evaluation of the impact of the introduced methods [8]. In literature, there are further models and approaches to increase the acceptance of methods in industry, e.g. [17]. Many of those authors deal with the question how to provide knowledge about methods. Beside the descriptions in literature like Pahl/Beitz [18], there are special books or collections containing several design methods, e.g. the Delft Design Guide [19]. Another way to describe methods and to provide the necessary knowledge about how to apply them are online platforms or, more recently, applications. An example for an online platform like that is the “Methodos” portal which was developed at TU Braunschweig with the purpose of teaching methods to the engineering design students in a more attractive and interactive way [20]. Beside different options to search for adequate methods, there are already method videos, helpful tools and templates attached to the method descriptions. Via comments it is possible to share gained experiences with other users. The first method application designed for mobile devices called “InnoFox” was presented in 2014 by the Karlsruhe Institute of Technology [15]. It provides a huge catalogue of design methods and various possibilities to access methods which are suitable to the situation given by the company’s surroundings [21].

The approaches and tools mentioned to transfer knowledge about design methods into practice directly or via a lasting design education can already solve some of the problems of design methods in practice. A promising further step is the combination with explanatory videos of methods, like they are implemented in the Methodos portal yet.

2.3. Explanatory Videos for the Knowledge Transfer

Explanatory videos are defined as short animated videos to explain a complex issue. In this contribution, the focus lays on method videos that describe design methods used within the engineering design process. Videos are a commonly used medium for giving a short overview of the issue to be explained. With the aid of pictures and sounds, the audience is addressed visually and aurally. If used correctly, this combination leads to a better understanding and increased memory performance by the spectator. For example, Chirumalla et al. conducted a study to identify the influences of the medium on an assembly process. The process was described with text only, with drawings and text, with pictures only and with a video. The video was best rated to understand these instructions as the combination of pictures and sound was helpful to the participants [22].

Looking at websites like Youtube, both the demand and the supply of explanatory videos, seem to rise further. There are various explanatory videos on diverse topics available. Giving the example of the youtube channel "explainity" which has currently more than 100 explanatory videos on politics, economics and health care online, shows the enormous demand for explanatory videos: the channel has more than 80000 abonnements and has had more than 8 million views since March 2011 [October 2016]. Especially students at high schools are used to watch videos provided online to complete knowledge gaps from the classes [23]. A survey among students from high schools concerning their usage, production and publication of online videos indicates that more than 60 % of them watch explanatory videos to prepare for exams and presentations. Similar findings can be reported for students with an academic background [16]. The main advantages of video based learning is seen in the increased individuality of knowledge acquiring. Videos can be stopped and it can be returned to a certain point when dealing with complex issues. Thus, regarding method videos, the method portal "Methodos" including several explanatory videos is provided supplementary to the lectures and exercises.

Summing up, the relevance of explanatory videos in both education and practice has been rising. Hence, in the engineering design context, the relevance of method videos in particular should be investigated, as these videos can be assumed helpful for transferring knowledge. In this context, factors that contribute to a successful transfer of knowledge from science to practice or in education are defined as success factors. Aspects that hinder the transfer are named barriers in the following.

3. Research and Methodology

The approach of this contribution is to use explanatory videos to teach design methods in design education as well as in practice. Both at Karlsruhe Institute of Technology (KIT) and at Technische Universität Braunschweig, several methods were produced as method videos and provided to students and industry partners within different case studies. The aim was to answer the following research questions:

- How is the acceptance of method videos in design education and practice?
- Which success factors of method transfer to practice can be addressed by method videos?
- Subsequently, what are the main elements of a successful method video?

In this contribution, three case studies will be presented. The results will be compared to identify the main elements of successful video forms and to gain information on the acceptance of the videos as medium to transfer method knowledge. In the end, the results will be used to match success factors of method knowledge transfer known from literature to the elements or characteristics of the method videos. This will give insights how to design successful explanatory method videos in general.

4. Case studies in Design Education and Practice

Before presenting the case studies in detail, the structure and general elements of the method videos will be explained.

The method videos at TU Braunschweig as well at KIT are set up in a similar style: there is always the protagonist. He or she is an engineer or engineering student who receives a task that he or she solves with the aid of the explained method. Thus, the video presents to the audience how the protagonist applies the method in question. In this way, the barrier to use the method in the following shall be reduced. The videos were created in a simple and attractive way using Microsoft Power Point or VideoScribe. The narrator tells the story around the protagonist and the method application off-camera. The repeating structure of these videos and the simple illustration are added by exhilarating supplements to enhance the entertainment value. The length of the videos is less than 7 minutes. Keywords are used for an easier understanding.

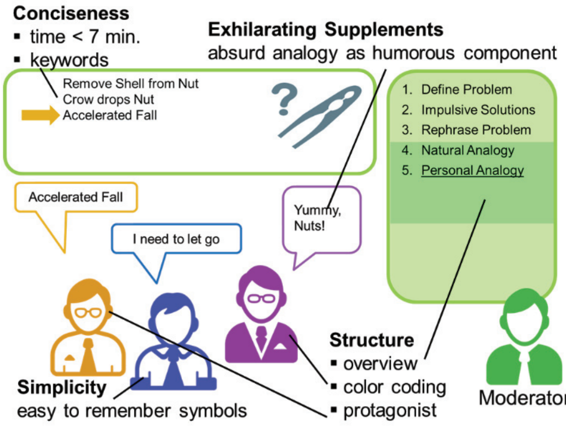

Figure 1: General elements and structure at the example of the Synectic video

Figure 1 explains the described elements at the example of the “Synectics” video. To get a better impression, the English version of the “Synectics” video can be watched on youtube (see https://www.youtube.com/watch?v=JO9UCELnVlI). In the following, this video is presented as the first case study in education demonstrating the benefit of creativity method videos. The second case study gives an insight into the medial support of risk analysis methods (FMEA) in student development projects. Finally, a study at Robert Bosch GmbH regarding design methods completes the sample.

4.1. Case Study Synectic in Education

The first case study to be presented was performed within lectures from the Bachelor and Master programs in the field of engineering design at Technische Universität Braunschweig. Accompanying the lectures and exercise classes the interactive method portal "Methodos" was introduced and provided to the students [20]. This online portal contains design methods taught in those courses. Beside verbal and graphical descriptions of the methods, several method videos are offered, e.g. explaining the Morphological Box, the Quality Function Deployment as well as Synectics. The purpose of these method videos is primarily for self-study. The students have free access to the videos via the method portal “Methodos” as well as in online courses. In exercise classes and in online courses, the students receive a small development task, in which they have to apply a method. The information on the method has to be found in the portal or through the videos. Teachers answer the students’ questions an give feedback on results in the present class or via email or the online teaching platform. Additionally, some videos are used in the lectures to demonstrate and explain the method. In this context, the above-mentioned method videos were evaluated within the corresponding courses during the past year.

In the following, the evaluation of the method video “Synectic”

within a bachelor course on basics of product development and engineering design in winter 2015/2016 is presented.
In the years before, the method was explained in the lecture using slides and a description in the lecture notes. This time, Synectic was explained only by the aid of the method video. Afterwards, the students evaluated the video via a questionnaire. The questionnaire consisted of two parts: the first part was a small quiz with three questions on the Synectic method. This served to figure out whether the students followed the video attentively, as the answers were not obvious. For each question there was only one correct answer. The second part of the questionnaire contains questions on the video in general but also on single elements to identify weak points and success factors of the video. In addition, the students were asked if they had known the method before.
52 valid questionnaires were returned. The results of the second part of the questionnaire are shown in Figure 2. All students estimated that they understood the method.

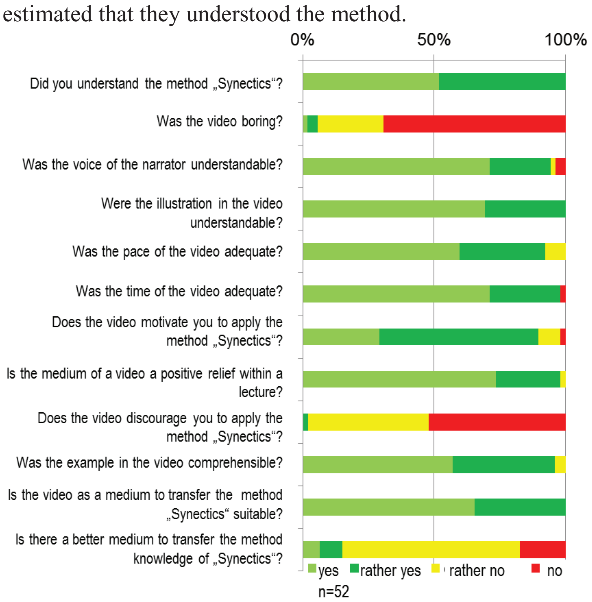

Figure 2: Results of the evaluation of the Synectics-Video (n=52)

Compared with the results from the quiz, this seems appropriate. Out of 156 answers in the quiz, only eleven were incorrect. Out of these, six answers were given by four students who indicated that they had known the method before (in total, ten students knew the method before). So, there is a successful transfer of the knowledge on the Synectic method for the main part of the participants. The voice and the illustrations of the video were about 75 % understandable and almost the rest “rather” understandable. The time is rated as adequate (above 70 %) and the pace at 60 % adequate. Except for 5 % of the students, the example in the video (development of an innovative nutcracker) was comprehensible or rather comprehensible to explain the method. The medium video was completely estimated as (rather) suitable. The students were not sure whether they could think of a better method, but mainly said “rather no” (about 70 %). Finally, 30 % of the students were even motivated to apply the method in the future. This happened one week later, when the students were given the task to develop a principle solution for a valve. Four out of eight teams chose the Synectic method and applied it. In comparison with the other teams (applying Brainwriting or Gallery Method), these teams came up with ideas inspired by nature which leads to more unconventional solutions. However, the Synectic teams gathered fewer solutions than the others did.
Overall, the Synectic video has a positive influence when teaching the method. The knowledge on the method can be transferred in a very fast way, independently of the teacher and in a motivating style. Success factors in this video are assumed to be the clear structure, the story with Tom as the protagonist and his experiences with the method, the simple illustrations and some exhilarating supplements that contribute to the entertaining effect of a video.

4.2. Case Study FMEA in Student Development Projects

The creation of explanatory videos for the methodological support of student development team is part of this section. Therefore, explanatory videos were created for the methods of 6-3-5, Sounding Board, Scrum, and FMEA. It is intended to arouse curiosity and encourage the students to take a more intensive look at methods. The videos should also make the entrance easier. This increases efficiency, reduces education and learning time and accelerates the implementation of new methods in processes. The aim of the explanatory video is to provide a guideline for the steps of a correct application of the method. Furthermore, an example is given which can be used as a template for the application. The video ends with a summary of all phases of the FMEA. This Video can be seen on (https://www.youtube.com/watch?v=JTI8Bm4kdkc).
The explanatory video for the FMEA has been validated in a validation study in the project "Integrated Product Development" at the Institute for Product Development. Here the students passed the whole product engineering process, based on an assignment of an industrial project partner. The results are shown in the Figures 3 and 4.

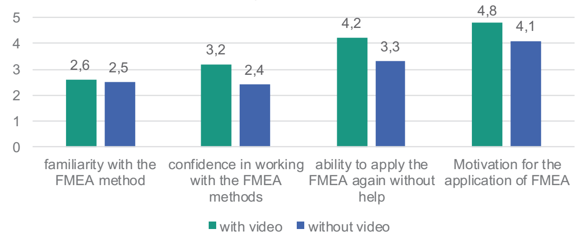

Figure 3: Increase of certainty and motivation of method application

40 people in total filled out the questionnaire. In the first block, the factors familiarity with methods, confidence in working with methods, learning experience, and motivation were queried. The survey was based on a scale from 1 (very low) up to 5 (very high). Figure 3 shows that a greater confidence in working with the method was felt among the groups who had seen the video before. The information was considered more useful than in the group that could prepare themselves only with a textual description. Figure 4 (left) focusses on the problems encountered in the implementation of the method. So, without the video, it was more often reported that there have been problems with the understanding of the context of the method. An even bigger difference can be seen in the terminology. Here, 27 % of the participants of the project groups with the video stated to struggle with the terms of the FMEA. The majority of the participants without videos report

problems with the terminology. Regarding the question how long the teams have estimated to be used until they could start with the FMEA (see Figure 4, right), participants without the video considered the time needed 1.5 minutes longer. This corresponds to approx. 12 % of the training time.
To compare the quality of the results, all possible causes of the errors were collected and declared as 100 %. The groups with video preparation found 69 % of the error causes in average, the groups without video preparation only found 57 %.

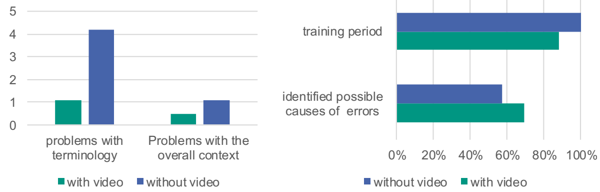

Figure 4: Problems (l) and success factors while applying the methods (r)

The validation study has shown that through the explanation videos both a positive impact on the quantity and the quality of the results was achieved. So, more error causes from a larger range of functions could be determined in the teams, in which the explanatory video was available. It was also evident that the method video has been used as a guideline and could help the teams to carry out the individual steps of FMEA correctly and completely.
In addition, it could be noted that the video helped to clarify fundamental issues concerning the method and its application.

4.3. Case Study: Guidelines for low-inductive Design

Another case study dealt with the mediation of complicated technical circumstances at the example of parasitic inductance. Since inductance is, actually, an electro technical phenomenon, many designers are not very familiar with it. Therefore, an easy explanation of the inductance should be given. Afterwards, the factors of influence were named and explained which specific influence they have on the inductance within the products. After the explanation of these basics, low-inductance constructions were examined in greater detail. To achieve a better learning quality, the duration of every video should be very short which is why the whole contents were split into two videos as follows.
Principles of inductance: Since in the described use case, the designers were excluding machine engineers, there is a need to clarify first the principles of inductance. Therefore, the video explains the definition of inductance, the influencing factors on the inductance and their influence on the components.
Guideline for low-inductive design: After the representation of the principles of inductance, the design guideline for low-inductive design is presented – based on the influencing factors of the inductance, which were already introduced in the first video. In the video, advantages and disadvantages of different solutions were presented. At bad designs, the way for an improvement is explained. With the help of the examples, the guideline is more understandable for the designer.
In order to evaluate the videos, a survey with experts was carried out. Built on the survey results, the following conclusions can be drawn:

- The provided videos are very easy to understand because of the help of graphic representation.
- The duration of the videos (in each case 3 minutes) came out to be appropriately valued.
- For presentation purpose, the explanatory video was preferred completed by links to relevant documents.
- The settling-in period in new subjects can be reduced by the videos.
- The video can be used as a reference source, especially for new employees and those who have no basic knowledge about the subject.

5. Resulting success factors of method videos within design education and practice

From the above presented studies, success factors of method videos can be derived. In previous work, e.g. [17][5][12], different success factors as well as barriers for method transfer to practice were described. In this contribution, the existing success factors as well as barriers were considered to identify fitting aspects with regard to the method video, as the results of the three studies show that the knowledge transfer with the aid of these videos has been successful. Starting with the barriers that can be avoided using methods videos, three main barriers were identified as shown in Table 1.

Table 1 Knowledge transfer barriers avoided by the use of method videos

Avoiding following Barriers	Implementation in Method Videos
Teaching Problems	once prepared and evaluated, the teaching remains on a high quality level; videos as a modern and thus motivating medium for teaching
Complex Presentation	simple descriptions by using examples and reducing information to a minimum required
Advantages not recognized	using context and examples to demonstrate exemplarily the benefits; success story

The first barrier to be named regards teaching problems, which can be avoided through a well-prepared and well-rated video with high quality concerning the content. Furthermore, the increase in popularity of explanatory videos suggests method videos to be modern and motivating to transfer and apply the knowledge. The second barrier is the complex presentation of methods, which is met by simple descriptions and examples within the videos. Finally, the problem of not recognized advantages is avoided by showing the context of the method application with the aid of an example and, hence, the benefits in the particular situation.
This leads to one of the key aspects contributing to the success of videos concerning the transfer of method knowledge (Table 2). Via stories told in the video, an emotional connection to the audience is built up, so the relevance of the method for the own design process becomes easier to understand. This reveals the success factors convincing and involving people to apply methods. Furthermore, the chosen examples in the videos demonstrate a success story and, thus, can be seen as a kind of a pilot project to convince the engineers of the method presented. The videos are short, so the time to learn the application becomes shorter. The recipient gains certitude in the application of the method, as the only the information needed for the application. Telling the story via the view of a protagonist being faced with a problem, shall lead to a higher motivation to use the method on own, similar problems. To

conclude, method videos in particular are supposed to show an additional value in the area of motivation, training time, variety of methods in the application, understanding and quality of results both in teaching and in industry.

Table 2: Success Factors of Knowledge Transfer

Success Factor for Method Transfer	Implementation in Method Videos
Involving People	emotional involvement, storytelling: protagonist who has a problem is presented. He solves problem by using a method; making the recipient curious
Convincing People	storytelling, demonstrating the relevance of the method for the own development process, using context, facilitating the entry, reducing learning times
Pilot Projects	storytelling, using context, using examples
Show Advantages	using examples, success story
Fitting Methods	using context, explaining why the method is relevant and suitable for a given task
Only provide relevant Knowledge	no detailed descriptions, no purely argumentative facts
Focus on Main Task	no detailed descriptions, no purely argumentative facts
Do not overtax the Recipient	relief of the cognitive system using a simple story, simple illustrations and reducing animations to a minimum
Adapt Methods	showing alternative ways (how and why)
Transparent Aims	success story, show aims and benefit
Dissemination of Safety	success story, show aims and benefit

6. Discussion and Conclusion

To answer the first of the previously defined research questions, it can be stated that the medium of video is well accepted in industry and education following the presented case studies. The question regarding the success factors for transferring (method) knowledge via videos was answered by deriving, in particular, the success factors storytelling, involving the recipient, combination of image and sound as well as lead by examples. So, some of the factors discussed in literature could be addressed. Furthermore, a better qualification of the user could be observed in the studies at the universities. However, most methods require a huge level of experience and knowledge. This experience may not be fully passed by an explanatory video and requires an instructor who is familiar with this experience and knowledge and has a great level of competence in the application of the method. Nevertheless, through the explanatory videos, the recipient received an overview and a basic understanding of the method in a short time. Additionally, the explanatory videos achieved a shortened training time as well as greater confidence in working with the methods. Nevertheless, to achieve these benefits, it is important to prepare a good method video. Besides giving an overview and a well-structured explanation, the main elements are simple illustrations and most notably a story with an exemplary application of the method. As an answer to the third research question, these elements were found essential within the presented case studies. In the future, there will be further effort spent to create more method videos to enrich the portfolio provided for design education and practice.

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