DERIVATION OF A METHOD DNA FOR THE UNIFIED DESCRIPTION OF METHODICAL PROCEDURES IN PRODUCT DEVELOPMENT

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ABSTRACT

The number of publications on methods in product development is increasing constantly. In addition to scientific models, method guidelines exist in practice to support the selection of suitable methods. When looking more closely, it is noticeable that new methods are not new developments of methodical principles, but rather adaptations and summaries of known methods to specific application areas.Although approaches to standardize methods exist, they are usually formulated too abstractly to be useful to project managers as a support for method decision making.In our contribution, we analyse common methods of technical product development regarding similarities in content and time. In doing so, we were able to derive a method DNA on the basis of which all methods can be described and, above all, distinguished in a verifiable manner. In addition to essential activity blocks, the DNA also includes the description of temporal sequences, which in particular enables a differentiation between agile and classic methods. Ultimately, the method DNA not only offers the chance to make methodical work comprehensible, but also the possibility to select methods specifically for upcoming development steps arises through the classification option.

Keywords: Design methods, Design methodology, Project management, decision support, method DNA

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1 INTRODUCTION

Product development, especially of technically complex products, is characterized by a decidedly methodical approach. Since the beginning of methodological investigations of product development in the 1960s (Cross, 2007), the number of methods has been growing continuously (Birkhofer, 2008). According to Birkhofer (2008) and Laukemann et al. (2018), these are indeed not new developments of methodological principles, but rather adaptations and combinations of existing methods to a specific use case. In practice, there is usually a repeated application of best practices, resulting in many methods not making the transition from science to practical application (Birkhofer, 2008).

However, the application of methods in practice is also influenced by trends: a transformation of the applied methods by agile methods has been observed in science as well as in practice (Reichelt et al., 2021). In the course of the agilization, not only new methods are used, but also classic approaches are questioned.

Ultimately, the introduction of new methods leads to an expansion of method collections, leaving project managers confronted with increasing confusion and thus growing complexity when deciding on targeted method support.

In this paper, we therefore investigate which basic characteristics and activities underlie the methodological approach in product development. Contrary to most approaches for this investigation (see chapter 2), we conduct the investigation analytically (see chapter 3). As a result, we present the method DNA. This DNA describes all the important, method-related characteristics to provide a basic understanding of methodological development in general as well as a possibility for classifying and modelling methods.

2 THEORETICAL BACKGROUND

As a basis for our investigation, we present the necessary theoretical background below. First, the distinction between the different types of descriptions in the literature is described. Subsequently, the different characteristics of the known methods are described (agile, classic, hybrid). Finally, the research gap is outlined.

2.1 Types of description for technical product development

The investigation of product development methods, as well as the classification and standardization have been subjects of method research since the beginning of the scientific consideration of product development (Birkhofer, 2008; Lindemann, 2009; Beier, 2013). In order to make the complex interrelationships of product development manageable, standardizations have already been made in the past (Lindemann, 2009; Ehrlenspiel & Mehrkamm, 2013). There are many descriptions in the literature which explain the procedure for technical product development in a model-like manner (Meboldt, 2008). Different foci of observation can be identified (Clarkson & Eckert, 2005; Birkhofer, 2008): The description of process models, general problem-solving steps and basic steps of development activities.

The description of process models usually describes the global context with central steps (Clarkson & Eckert, 2005). According to Wynn & Clarkson (2005), different approaches exist for these descriptions: A distinction can be made between phase-based and activity-based models, which are based on either an abstract, analytical, or procedural approach. Here, a process can be prescribed - as an ideal conception - or described as a derivative of a real process (Wynn & Clarkson, 2005). These models attempt to provide an all-encompassing and, above all, understandable and thus comprehensible and easily adaptable support by reducing them to essential development steps (Wynn & Clarkson, 2005; Lindemann, 2009; VDI 2221). Examples for a phase-based, abstract and prescriptive process description are the VDI guidelines 2221 and 2206, or the ISO/IEC/IEEE 15288 guideline as well as the Munich model according to Lindemann (2009). For an activity-based, procedural and prescriptive description, the SPALTEN model according to Albers (2002) and the innovation process according to Vahs and Burmester (2005) can be mentioned.

Problems are fundamentally solved in the context of product development (Meboldt, 2008). So-called problem-solving cycles exist as a description for the solution of problems in product development. By repeatedly applying the described steps, a solution is to be successively developed. Examples of cyclical procedures are the TOTE scheme according to Miller (1960) and the PDCA cycle according to Deming

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(1986). The PDCA cycle in particular is considered an essential basis for methodological development (Lodgaard & Aasland, 2011; Lindemann, 2016) and an approach for incremental process improvement.
The problem-solving cycles are intended to be based on human thought and action and to address problem solving at the individual level (Meboldt, 2008; VDI 2221). These basic patterns have also already been studied in science (Birkhofer et al. 2005). In this context, the thinking and design actions in the development of technical products were examined in more detail. Examples for these considerations are the studies of Wallas (1926); Hacker (2002); Cross (2007); Sawyer (2012).
In principle, these models can be used to model development projects at basic planning and control levels and provide a general orientation aid, especially due to the intended generality of these models. In terms of a specific operationalization of development tasks, or the selection and implementation of appropriate methodological support, there are only method manuals and generalized method recommendations. Especially in the context of the continuous development of methods and the ongoing change of methodological maps in companies, also with regard to the implementation of agile methods, known process models as well as established method collections are increasingly losing their effectiveness and thus their relevance as support for PMs. It is therefore logical that in practical implementation, well-known methods that have already been applied are usually used.

2.2 Characteristics of agile, classic, and hybrid methods

In addition to the general types of descriptions that primarily address the sequence and procedures of development projects, there are three main characteristics in the current world of methods into which methodological approaches can be divided (Timinger & Seel, 2016; Wysocki, 2019; Heimicke et al., 2020; Reichelt et al. 2021): agile, classic, and hybrid.
Classical methods are currently considered the standard in the development of technical products. These methods are characterized by a high degree of plannability and a sequential sequence of work steps. In most cases, classical methods are based on defined milestones and quality gates. An example is the stage-gate process according to Cooper (2007). These methods are used primarily when defined quality targets, which are usually specified externally, must be met at certain times and maturity levels (Reichelt et al. 2022a).
Agile methods have their origins in software development and are characterized primarily by a high degree of flexibility and adaptability of content-related and time-related targets (Böhmer et al., 2015; Albers et al., 2019b; Reichelt et al., 2021). This is achieved, among other things, by short iteration cycles. By means of these, a regular review of increments (MVPs) and the associated continuous adaptation and improvement takes place. Thus, agile methods are particularly suitable for complex and unclear development situations (Boehm and Turner, 2005; Albers et al., 2019a).
Even though agile methods are now an integral part of the development environment, a complete switch to agile methods is not considered goal-oriented or possible, so that a hybrid application of classical and agile methods can be assumed to be safe (Timinger & Seel, 2016; Heimicke et al., 2020; Reichelt et al. 2022a). There are various ways in which agile and classical methods can be combined (cf. Timinger & Seel, 2016; Reichelt et al. 2022a). Currently, however, agile methods are primarily integrated into classic development environments (Heimicke et al., 2020), which means that the actual benefits of the respective methods are not sufficiently effective.

2.3 Research gap

There are numerous methodological procedures for technical product development which cover a wide range, particularly with regard to the types of description and thus the level of detail. In order to provide adequate methodological support for complex development work, PMs should understand and take into account all facets of the development process (Wynn & Clarkson, 2005; Cross, 2007). Although comprehensive method collections and models of product development exist, these either have a description that is rather abstract, so that an application is not exactly possible, or the models provided have too strong focus, i.e. are too problem-specific, or are themselves too complex; for example, the SPALTEN activity model consists of 70 activities and ISO/IEC/IEE 15288 has a collection of 30 sub-processes.
In addition, a sequential process is described in most cases, which does not take place in practice (Meboldt, 2008). Therefore, best practices are used in practice, which means that the potential of individual methods remains unused. For example, there are currently no reliable parameters that can

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be used to decide between the use of agile and classic methods (Bender & Marion, 2016; Taylor & Ahmed-Kristensen, 2016; Reichelt et al. 2022b).
In order to decide from a selection of possible methods, there should be a basic knowledge of what methodical work can look like in the first place. Therefore, a basic structure of methods or a description is necessary, which can be used to understand any method.

3 METHODOLOGY

Based on the identified research gap in Chapter 2, we have formulated the following research questions for the targeted investigation of a basic knowledge for methodological product development:

RQ1: What are the basic elements of the methodical development of technical products?
RQ2: How can the wide variance in methods and approaches be justified?
RQ3: How do agile and classic methods differ?

To answer the first research questions, we followed the approach of Birkhofer (2008) and first examined known methods and methodologies with regard to *"method-inherent basic procedures"*.
To this end, we first conducted a systematic search for relevant methods and methodologies that directly or indirectly affect technical product development - e.g., accompanying processes. The research resulted in a total of 31 relevant methods. In addition to methods for product development, project management methods are also included. On the basis of a generalized process landscape, it was examined whether methods for the relevant processes are present in the collection, so a certain completeness of the methods could be proven. In order not to let the detailed investigation become too extensive, a selection had to be made, which was done by experts. The expertise is based on the one hand, on 25 years of experience in project management and product development and in methodical process optimization, and, on the other hand, on many years of scientific study of product development methods. 11 methods were defined, which comprise the "standard" of today's product development methods (see Table 1).
These were examined with regard to similarities and differences in terms of content and procedures. The goal of the investigation was the analysis whether typical, i.e. recurring work steps exist throughout the methods. In addition to the original sources, which basically describe the procedures of the methods, examples of application or further literature were also used to assess the exact work content.

Table 1: Overview of the examined methods of technical product development

basic methods	8D-Method	Design-Thinking	V-Model	Value Management	PDCA	
	Scrum	Stage-Gate	Project Management	PKEA	Industrial Design	Waterfall
methods for validation	Method 365	Balanced Scorecard	Benchmark	Brainstorming	Hoshin Kanri	Value Analysis
	Kaizen	OKR	Kanban	Six Sigma	Market Segmentation	TRIZ
	QMS	Poka-Yoke	Extreme Programming	PRINCE2	MbO	QFD
	Risk Management	Scrumban				

As result of our analysis similar work steps or activities could be found throughout all methods regarded. These similar activities can be converted into uniform blocks. Due to their chosen level of abstraction, these are coexisting in the variety of all methods. Through these blocks the technical product development can be described from the initial idea to market launch. To validate the blocks, the remaining 20 methods (see Table 1) were examined to determine whether the identified blocks could also be found in these methods. The examination showed that the clear majority of the blocks can be found in the 31 methods overall considered. In total, only 3 blocks were identified, which are described only in isolated cases in several methods. These blocks were discussed by the experts of the

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methodical product development. During the discussion, the content of two of these modules was integrated into existing blocks. One block was subsequently removed because the content was too specific for a method.

The validation of the blocks provided important insights into the existing variance, particularly for answering the second research question.

In order to answer the third research question, it was not sufficient to break down the methods into content-related blocks. Therefore, the temporal sequences and sequences of methodical steps of the methods were examined in more detail. Thereby further components resulted, how methods can be described unified.

Finally, all findings were summarized in the method DNA. Figure 1 visualizes the approach in this paper, which is characterized by two convergence and one divergence phase, in order to investigate the three research questions.

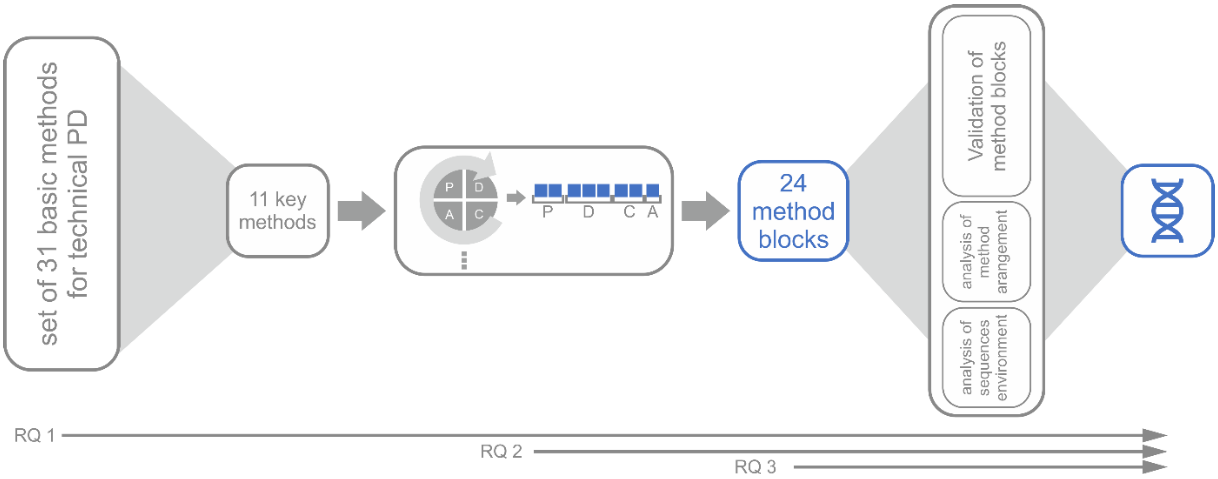

Figure 1: Methodical procedure for the creation of the method DNA

4 RESULTS

In the following, we present the results of the method investigation individually. The combination of the method blocks, sequences and arrangements ultimately form the method DNA, which we will present in more detail as the conclusion of this chapter.

4.1 Method blocks

Based on the analytical examination of the 11 methods determined by the experts as central methods of technical product development, 24 method blocks were identified. Each block represents a general work step or activity in product development, which can be carried out simply but also repeatedly in the course of a development process. The building blocks can be divided into 9 categories: *Requirements*, *Team*, *Analysis*, *Target / Goal*, *Solution generation*, *Solution rating*, *Realization & Marketability* as well as *Launch product*.

Figure 2 presents the identified blocks, as well as the assignment to the categories.

The review showed that the clear majority of the blocks (70%) are found in 30% or more of the 31 methods considered. Not all blocks appear equally in each method: Methods typically consist of several blocks. It is not necessary that all blocks are used in a method. Most blocks are found in methodologies and systematics since these cover a broader description of the product development.

By the verification it could be determined that methods possess different foci, so some methods put the focus on the *analysis*. This shows up by the fact that within these methods above all these blocks are used. Furthermore, no differences could be found between agile and classic methods with regard to the application of blocks, so that a further investigation was necessary.

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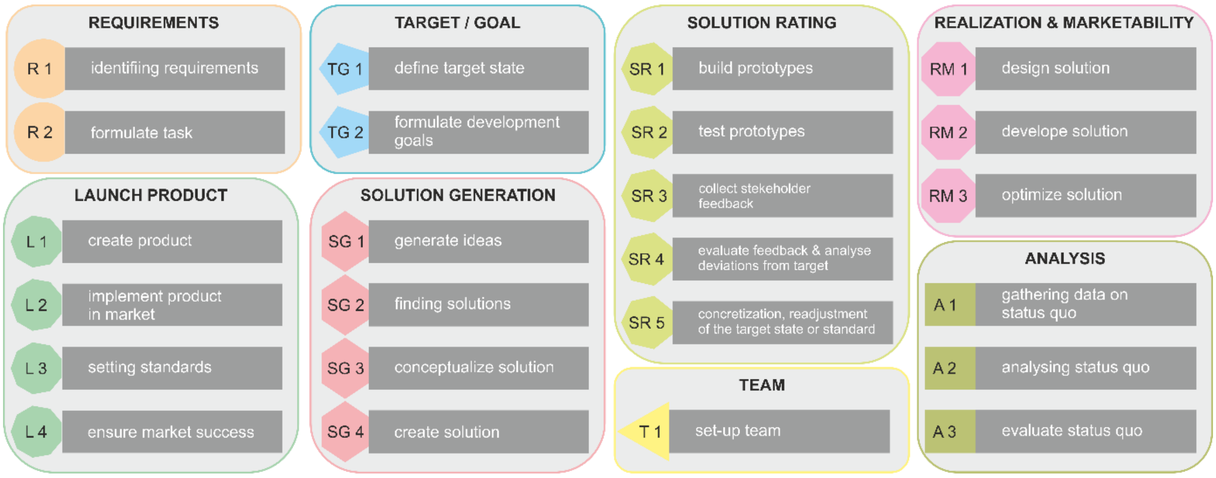

Figure 2: Overview of the 24 method blocks

4.2 Block arrangement

When looking at agile and classic methods (cf. Scrum and V-Model), it became clear that both methodologies have an approximately equal distribution of blocks used. The blocks used do not differ significantly. In order to be able to explain the actual differences between methods (see RQ2 & RQ3) a pure consideration of the content blocks was not sufficient. Therefore, we extended the investigation to the arrangement or sequence of the blocks. In the literature, different ways of arranging process steps or activities in product development can be found (Blessing, 1994; Vajna, 2005): sequential / serial; iterative / cyclical; parallel / simultaneous or congruent.

When transferring this basic idea to the blocks, it becomes apparent that the core difference between methods is the arrangement of the blocks used.

Methods declared as agile are characterized by a higher iteration of identical building blocks. Whereas classical methods rather choose a stringent, sequential or parallel/simultaneous sequence. Figure 3 attempts to illustrate these principles using the examples of Scrum (Schwaber & Sutherland, 2021) and the V-Model (VDI 2206).

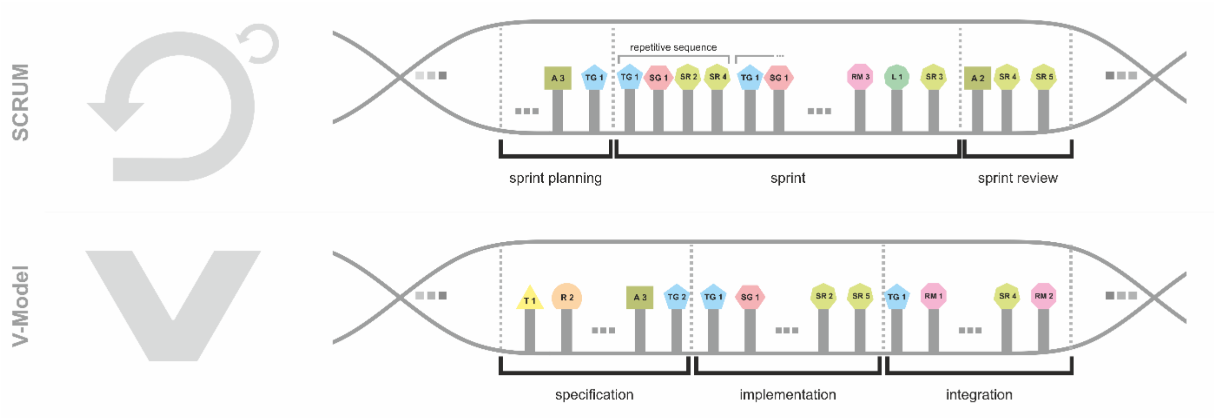

Figure 3: Comparison of the different arrangement of method blocks for Scrum and V-Model example blocks of Scrum and V-Model

In addition to these arrangements, other correlations could be found, such as block sequences, which cause differences in methods and methodologies.

4.3 Block sequence

Based on the blocks, entire development processes can be modelled, in particular through the arrangement of these or the associated categories. During the exemplary consideration of Scrum and the V-Model (see chapter 4.2), it was noticeable that there are sequences of blocks which repeat themselves. These sequences mostly consist of blocks of the category's *Analysis*, *Target / Goal*, *Solution generation* and *Solution rating*. This corresponds in a figurative sense to the classic PDCA cycle according to Deming (1986).

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Furthermore, it is noticeable that in the modelling of an entire PDP, some blocks are only used at certain temporal events. In particular, the blocks from the clusters *Realization & Marketability* and *Launch product* are applied more towards the end of product development than in the early phases. This is logically related to the temporal progress and the corresponding maturity of the product. On the other hand, other blocks can be found repeatedly in the PDP, mostly in the form of the sequences described above.

4.4 Method DNA

By combining the method blocks (chapter 4.1), block arrangement (4.2) and block sequences (4.3), a unique description is created in total. With the help of this set a methodical procedure can be completely characterized and, above all, reconstructed. This unique description allows an exact determination of a method; it represents the DNA of the method.
Figure 4 depicts the interrelationships of the method DNA. A method is ultimately composed of the four components: block, arrangement, sequence and environment. The use as well as the sequence of the blocks describe the activities which are carried out. The arrangement allows conclusions to be drawn about the chronological sequence, so that a serial or iterative procedure can be identified. Sequences can be used to determine typical clusters of activities that are performed repeatedly.
The fourth component of the method DNA is the environment. The environmental conditions in which the method is applied have a significant influence on the operational work. Therefore, the environmental factors represent unique influences for adjustment of the methodical procedure in the development process. According to Bender & Gericke (2016) there are so-called contextual factors that can describe the development environment and influence the methodical work.

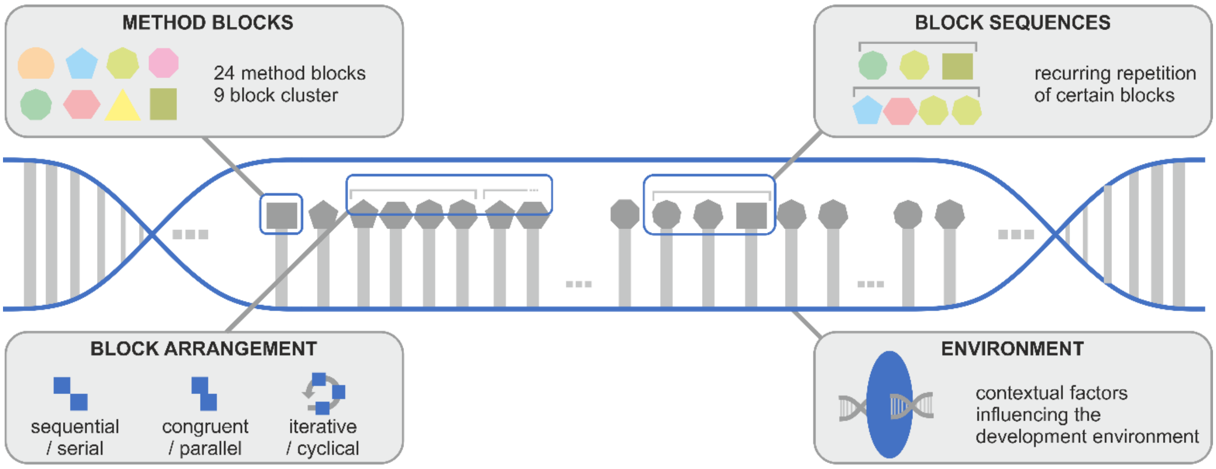

Figure 4: Composition of the method DNA as a unique description of a methodical approach

In the description of a DNA string, the various influencing factors of methods can be shown in detail. In addition to the sequence of the blocks, the differences between agile and classic methods can also be illustrated. Agile methods have a shorter string since the applied blocks are only planned up to a certain point in time and only after completion of this period a new planning takes place (cf. Sprint in Scrum). Classical methods, on the other hand, have a much longer string; the selection and arrangement of blocks is fixed and planned.

5 DISCUSSION

Overall, we were able to answer all research questions. Our analytical investigation showed that common methods of technical product development are based on 9 block categories. These basic blocks can be found in different methods and could therefore be verified by looking at further methods. In contrast to known, activity-based descriptions, a methodical procedure can be described or modelled comprehensibly by a small number of 24 method blocks. Other models, such as the SPALTEN model, describe the product development activities in great detail, so that specific knowledge must be available when applying or adapting them to your own models. On the other hand, models are also described abstractly, so that there is a lot of room for interpretation and thus uncertainty in the application.

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The method DNA derived from our investigations visualizes the essential aspects of methodical work and therefore does not require a broad understanding of methods. By the combined description of the blocks as well as the arrangements, regular sequences as well as the environmental factors, each method can ultimately be described clearly and comprehensibly. By the chosen degree of abstraction, a support on individual, operational level is conceivable, but not in the focus. The mental models are found rudimentarily in the categories of the method blocks. However, the exact processes involved in individual problem solving are so person-specific and therefore too complex for generalization.

Even if it is possible to reduce the content to 24 essential method blocks, the possibility of combining the blocks in different content sequences alone in a purely sequential arrangement creates a variance that cannot be estimated. Beyond that the differences, which exhibit different methodical procedures, can be justified above all by the arrangement of the method blocks: In particular, the continuous iterative arrangement of blocks and certain sequences distinguishes agile methods from classical methods.

As a side effect we could furthermore determine that known methods can be classified by the decomposition into the method blocks and the appropriate categories: Not only by the arrangement a statement about an agile or classical characteristic can be made, but much more a focus of a method, e.g. on the recording of the status quo, can be determined, if the appropriate blocks are used with priority.

The method DNA developed here originates from the investigations concerning the technical product development. However, during the processing it became clear that the method DNA can be scaled arbitrarily. On the one hand, the components of the DNA can be used to model and reproduce entire development processes. On the other hand, it is also possible to represent simple problem-solving procedures on a direct operational level. As an example of an upscale, Lessons Learned can be applied to an entire process as part of the block *"concretization, readjustment of the target state or the standard (process)"*.

During the final elaboration of the DNA components, already completed projects were re-rolled in order to check the method DNA additionally for plausibility. However, for reasons of space and, above all, secrecy, it was not possible within the scope of this article to show any practical examples that underline the applicability of the DNA.

Furthermore, this exemplary recapitulation showed that a transferability of the method DNA to other industries and use cases is conceivable.

The environment has only been treated superficially in this contribution, but it has a central effect on the applicability and, above all, the success of methods. Thus, the human factor plays a decisive role in methodical procedures.

Finally, the method DNA is based on a qualitative analysis of known methods and methodologies: these were qualitatively examined and compared in terms of content. A translation into a quantified study layout was not possible due to the strong variance in the method descriptions.

6 CONCLUSION AND OUTLOOK

In conclusion, we were able to present a method DNA by means of which a basic understanding of methodical work can be traced. This basic understanding enables the unified recapitulation of methods and furthermore the modelling of adapted procedures in technical product development.

It is particularly interesting whether inexperienced method users can control method application, but above all the combination of different methods better than so far.

However, further steps are necessary for this examination of approval. To provide all relevant information, the individual method blocks should include detailed description following Vajna (2005).

Apart from this content level development of the environmental factors is necessary. Due to our results is came apparent that besides the type of arrangement the different contextual factors have a huge impact on the purposeful choice and application of methods.

Therefore, a match of the method DNA with decision points in known product development processes is also needed. In particular, the subdivision into design decisions and method decisions in the early phase demanded by Reichelt et al. (2022b) represents a next concretization step with regard to a situation-related support for project management. This requires also a quantifiability of the previous qualitative analysis, so that a decision support can be made possible regarding the situation-based method choice.

All in all, the method DNA presented here represents the cornerstone for a user-oriented method discussion, on the basis of which a support of project managers regarding the target-oriented methodical development can also be made possible in the application outside of science.

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