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# METHOD RECOMMENDATION AND APPLICATION IN AGILE PRODUCT DEVELOPMENT PROCESSES

N. Reiß, N. Bursac, A. Albers, B. Walter and B. Gladysz

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## 1. Introduction

Across Europe, development-intensive industries such as mechanical engineering, automotive, medical engineering and electrical engineering are the major pillars of economy. Nowadays innovations are required in even shorter cycles. Development projects must be quicker, cheaper and still finished in high quality. This means at times breaking with sequential development processes. It is necessary to respond faster to market changes. Established methods and processes (e.g. Product development processes and production processes) are not designed for these requirements and reach their limits. Agile process frameworks expose untapped potential. When choosing agile processes some peculiarities should be considered. Considering the fact that knowledge generation, validation, and documentation are decisive aspects of product development, a key role is played by efficient knowledge handling throughout the entire product development process. However, since the existing knowledge is uncertain and vague, in particular at the early stage of a product development project, a systematic handling of process and product knowledge will become increasingly important. Such systematic approaches may be supported by appropriate methods. The research project IN² was initiated to increase the innovation potential by means of suitable methods and processes. The objective of the project is to support systematic product development by selectively combining the inseparable elements of process management, methods management and knowledge management. One result of the project is the InnoFox which is an application for mobile devices and is intended to enable putting into practice obtained project results by providing specific product development methods. Developers can define their current situation within agile and iterative product development process, their available resources (e.g. the number of persons), the desired objective, and the type of document to be developed. Based on these data, the InnoFox provides proposals of methods that can support users in their specific situation. After giving an overview of the project results obtained so far, this paper describes the research methods of the IN² project. Section 4 discusses the compilation of methods and the respective selection criteria. Based on these details, interactive methods recommendation is introduced. Finally, the results of the project are summarized and presented by means of the demonstrator of the InnoFox virtual methods coach.

## 2. State of research

### 2.1 Application of methods

Development and innovation management provide various methods for the support of development processes. The term “method” is often understood as a rule-based planned sequence of activities

[Lindemann 2009]. So far, some methods e.g., quality function deployment (QFD) or morphological boxes, have been widely used in firms and companies. Due to the lack of know-how regarding an effective integration into the product development process, methods beyond these well-known ones are only used to a restricted extent [Jänsch 2007]. In this context the distance between science and practice is often criticized resultingin a lack of acceptance of methods and a lack of awareness of prospective suitable procedures at the developers' side [Pahl 1994]. A demand- and situation-specific supply of methods to product development processes hence should be an important objective of methods research. The preparation and tailor-made appropriation of such ample possibilities play a key role in the transfer of methods from research to practice [Graner 2012]. This purpose is addressed by digital applications such as websites or methods manuals. The application limits of such platforms, however, are quickly reached: Existing solutions presently only offer a search function for proven methods within selected innovation activities, a method profile, and a service for finding methods experts (service providers). Since, a specific approach for selection and integration into development processes hardly exists, mostly only the most well-known methods are consulted whereas the great potential of new methods remains largely unused.

### 2.2 Knowledge management

Since the success of product development processes also highly depends on the knowledge and experience of the participating engineers the availability of appropriate method information must be ensured at an appropriate time. This, however, is not always possible on account of different factors of influence e.g., due to deadline pressure [Probst et al. 2013]. Knowledge management, understood as a comprehensive organizational intervention concept, provides a large variety of tools and methods that help to optimize the handling of knowledge, data, and information [Roehl 2000]. To be efficient, the available tools and methods of knowledge management, on the one hand, must be applied taking into account the specific situations. On the other hand, in order to circumvent or avoid knowledge barriers, it must be ensured that the respective methods are accepted by the staff [Brecht-Hadraschek 2004]. In product development practice there is a high demand for selecting knowledge management tools and methods in accordance with the specific situations and for implementing them with little effort.

### 2.3 The IN² Project - From Information to Innovation – achievements

To investigate the combination of methods, processes, and knowledge management, an iPeM-based modeling technique was developed within the IN² project. This technique enables the demonstration of central knowledge flows within PEP. It was tested within the framework of an explorative preliminary study conducted by the Formula Student Team KaRaceIng [Albers et al. 2013]. Figure 1 depicts the modeling technique based on activities (1), supporting methods (2), and the used (3) and developed (4) knowledge objects.

The activity-based modeling technique was subsequently applied with the objective of analyzing the correlation between methods and process steps for five IN² project partners from companies of miscellaneous size and branches (e.g. utomotive, equipment construction, aerospace) . It was found that many of the respective activities so far have hardly been supported by tools or methods [Albers et al. 2014a]. By means of the technique, potentials, such as the avoidance of redundancies, were pointed out and the product development process was supported by implementing tools and methods [Albers et al. 2014b].

Moreover, an empirical study with 131 engineers was carried out within the project to find out the significance of certain method categories and to assess whether there are variations in the quality and quantity of methods used during agile product development processes. According to one of the key results, certain method categories have been preferred over others. Yet, it is surprising that specific elements of method categories are used throughout the PDP. In addition, it was found (Figure 2) that although some specific methods are applied by firms and companies (98 percent apply creativity methods) many users restrict themselves to the conventional methods even though these are hardly rated better than the less often used methods [Albers et al. 2014c].

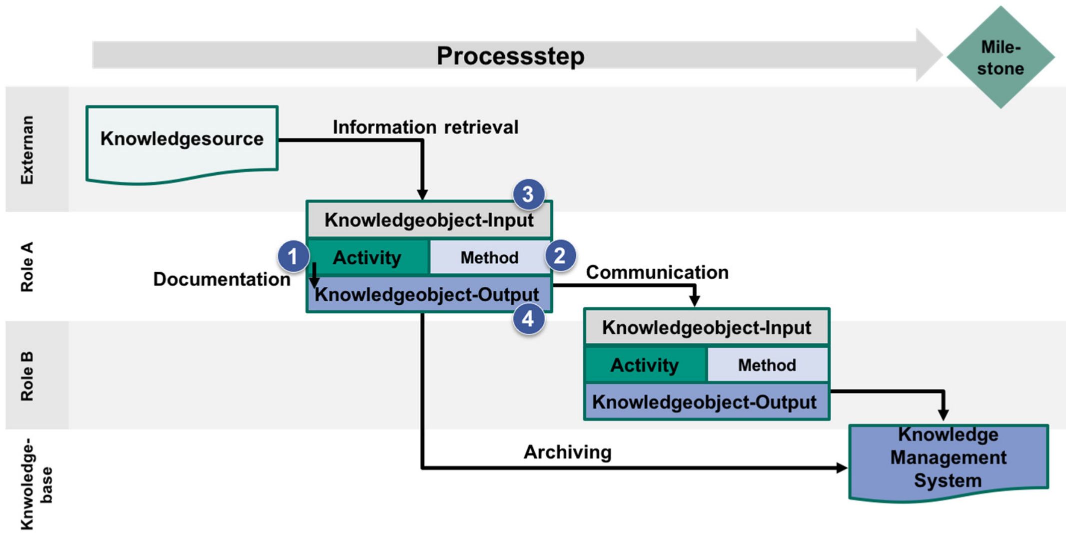


**Figure 1. Activity-based modeling technique [Albers et al. 2013]**

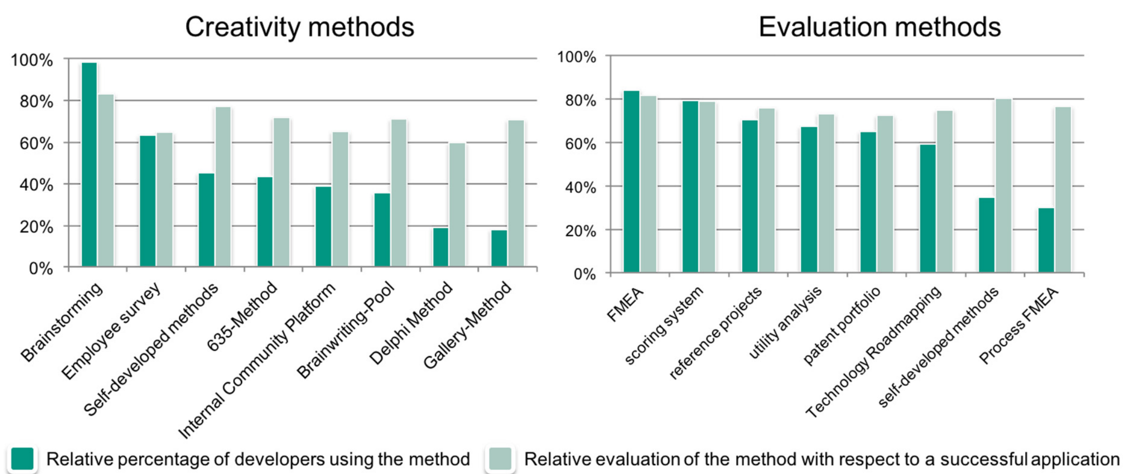


**Figure 2. Use and evaluation of methods in different areas of application**

The above leads to the conclusion that methods often are selected with a view to well-proven schemes and that less often, users try to find out whether there are methods that could suit a particular PEP situation better. As a result, a large variety of methods are developed but not used widely.

Due to the fact that many of the less-used methods have been rated as being successful one objective should be to enable the developer to apply new methods that suit in the relevant situations. The spreading of such new efficient methods could also broaden the horizon of developers and, in turn, enable a more efficient product development [Albers et al. 2014c]. To be able to recommend specific methods a recommendation algorithm was developed which provides an individual ranking of the best-suited methods based on the ZHO model [Albers et al. 2014d]. This paper intends to find out how, in accordance with the respective situation, hands-on methods can be integrated into the individual processes of agile product development.

## 3. Research method

Agile product development processes are characterized by a high number of iterations which, however, can hardly be represented and planned sufficiently using the conventional process models [Lohmeyer 2013]. In view of this fact, it is important to support product developers with suitable methods in accordance with the specific situation [Albers et al. 2014a]. This is enabled by coupling of product development processes and supporting methods. The integrated product development model (iPeM) describes product engineering as a continuous interaction of the system of objectives, the system of objects and the operation system [Rophol 1975], [Braun 2013]. Based on the system theory, the goal here is to transform a system of objectives into the system of objects [Albers 2010]. The system of objectives comprises all explicit targets of a product that is to be developed including their dependencies and boundary conditions within a defined area of interest (i.e. within a system of interest) at a certain time. At the end of the development process the system of objects corresponds to the product. This conversion is done by the operation system. The system of objectives and the system of objects are linked by the operation system. There is no direct interdependency between the system of objectives and the system of objects. The operation system is a socio-technical system that is composed of structured activities, methods and processes as well as the needed resources for the realization, e.g. design staff, budget, material, machines, etc.. The integrated product development model is composed of different fields of action of product development (1 in Figure 3) and diverse activities of problem solving referred to as SPALTEN process (2)[Braun 2013]. SPALTEN is an acronym and stands for the sub-steps of this problem solving method: Situationsanalyse (situation analysis), Problemeingrenzung (problem definition), Generierung Alternativer Lösungen (generation of alternative solutions), Lösungsauswahl (selection of solutions), Tragweitenanalyse (analysis of implications), Entscheiden und Umsetzen (decision and implementation), and Nacharbeiten und Lernen (reworking and learning) [Albers et al. 2005]. This results in a two-dimensional matrix with 70 activities (3) to which different methods can be assigned.

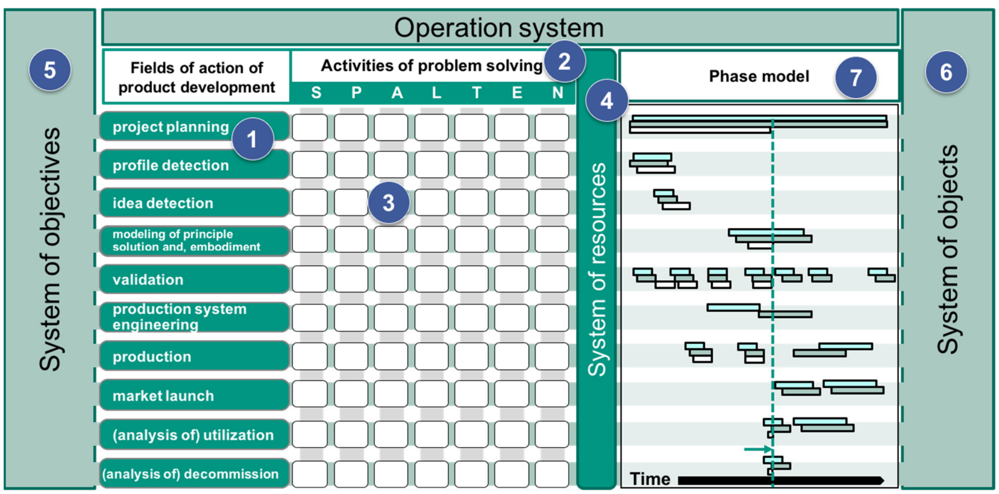


**Figure 3. Integrated product development model (iPeM) [Albers et al. 2011]**

By means of these activities and based on the available resources (4), the targets of a PEP (Product Engineering Process) (5) are successively transferred into artifacts or objects (6) which, in most cases, leads to an iterative further development of targets. The PDP is scheduled within the so-called phase model (7) [Meboldt 2008].

The IN² project mainly consists of three steps: Step one was dedicated to structuring the known tools and methods based on the current state of research and technology. For that purpose, diverse sources such as existing collections of methods or relevant literature were reviewed and documented in a project-specific **collection of** around 130 **methods**. To ensure maximum practice orientation this list of methods was extended by data obtained from the project partners from the industry (n=7) and from the scientific institutes (n=2) participating in the project. The spectrum of the compiled methods in particular comprises the areas of product development, knowledge management and future management. Step two included the analysis, the clustering and evaluation of the respective tools and methods. Criteria for evaluation of the methods were developed within the framework of a workshop with all project partners (n=9) and were then converted into an interactive **methods recommendation**.

To implement a situation and demandspecific selection of methods, selection criteriawere determined and assigned to the dimensions of the iPeM. These dimensions are related to the suitability for achieving specific targets in product development (system of objectives), the suitability for certain activities within product development and problem solving including the required resources (operation system) and the suitability of methods for developing specific knowledge objects (system of objects). To make this iPeM-based logic accessible to every user group an interactive access element was developed which supports users in the assignment of situations and allows them to represent specific application situations in InnoFox either by selecting suitable iPeM fields or using a short question dialog, thus making the specific situations available to the InnoFox selection algorithm for deriving suitable methods recommendations.

## 4. Results

### 4.1 Method collection

The discussion about methodic product development has been often described in the literature. The IN² project hence is based on various theoretical sources and intends to identify and, if required, improve particularly practice-oriented tools and methods from a comprehensive collection of methods. In that way more than one hundred methods of product development, of knowledge management and future management have been compiled. These methods have been identified mainly by means of specially developed standardized method profiles. Particular emphasis was placed on the high quality of theoretical contents and on the usability in practice of the method profiles. To achieve this, the participating partners were invited to take part in the formulation and validation of the contents.
The method profiles are based on specified module contents that are intended to give developers a quick overview of the respective method and to support them in method application. The modules are as follows:
*Abstract, advantages / disadvantages, brief description, input / output, main work steps, supporting tools, alternative methods, sources / literature and experts*.
Additional selection criteria were compiled within the framework of the project to support a situation- and demand-specific selection of methods and ensure the suitability of methods for achieving specific targets in product development (System of objectives), the suitability for certain activities within product development and problem solving including the required resources (resources system), and the suitability of methods for developing certain knowledge objects (System of objects). Figure 4 summarizes the selection criteria determined by means of iPeM [Albers et al. 2014d].

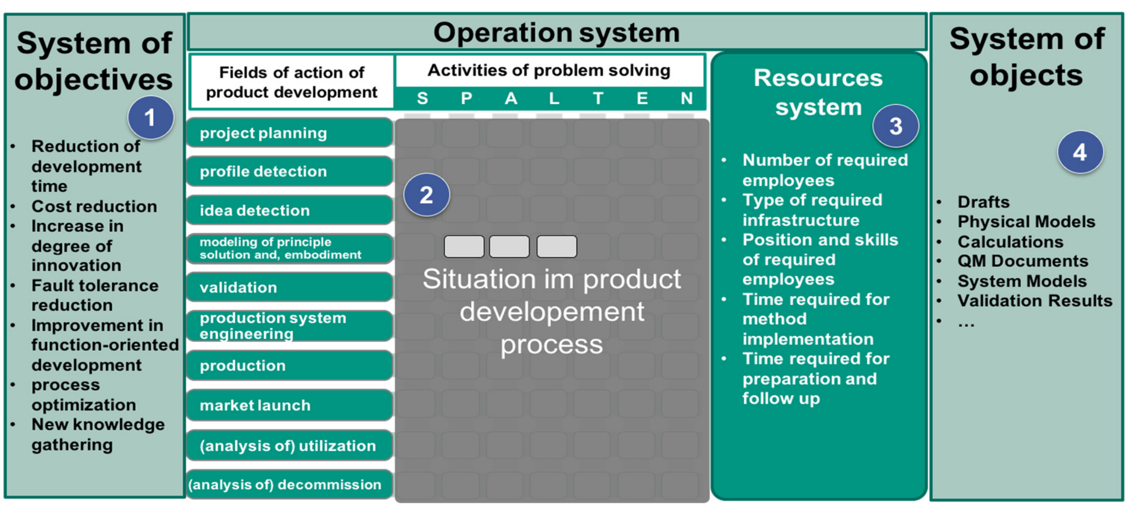


**Figure 4. Method selection systematics based on iPeM**

To develop a well-founded basis for method selection target criteria, targets of method application were compiled by conducting searches and interviews and were summarized into seven general target criteria

[Birkhofer et al. 2002], [Braun und Lindemann 2004]. The following seven target criteria were derived for method application (1 in Figure 4):

1. Reduction of development time
2. Cost reduction
3. Increase in degree of innovation
4. Fault tolerance reduction
5. Improvement in function-oriented development
6. Improvement with regard to process optimization and interdisciplinary cooperation
7. New knowledge gathered by the involved persons in terms of users' learning process

The empirical survey presented in Section 2.4 [Albers et al. 2014c] enables an assignment of the respective methods to the 70 activity fields of iPeM (2 in Figure 4). Based on the results of the analyses and surveys, methods within the activities of product development and problem solving were classified (from 0 - not suitable to 5 - very well suitable).

The resource system was specified based on the criteria for method characterization described in the literature [Birkhofer et al. 2002]. The pool obtained in that way was concretized within six expert interviews and was reduced with regard to the criteria most relevant to method selection. The five resulting criteria of the resource system (3 in Figure 4) are:

1. Number of required employees
2. Type of required infrastructure
3. Position and skills of required employees
4. Time required for method implementation
5. Time required for preparation and follow up

Based on a process survey among the industrial partners within the IN² project the main knowledge flows in the respective phases of product development and the types of knowledge objects used for information transfer were documented. Prototypes are also regarded as knowledge objects since they represent the knowledge needed for their development. Within the analysis of knowledge flows 43 different knowledge object classes were identified and collated into 12 groups (4 in Figure 4). Subsequently, the individual methods were evaluated with regard to their suitability for development of the respective object.

### 4.2 Interactive methods recommendation

In the InnoFox situation and demand specific methods recommendation was realized by means of an interactive iPeM-based access element. By selecting the relevant activity in the iPeM matrix as well as the intended targets of method implementation and the targeted results to be developed, the individual situation can be determined precisely. After entering the data about the respective application case, the selection algorithm calculates a congruent value for all methods stored. This congruent value represents each method's suitability for the respective application case. From methods stored in InnoFox the most suitable ones hence are selected and classified according to their congruent value.

The congruent values are calculated within the framework of a value benefit analysis that compares the attributes entered by the users for characterization of their specific application cases with the characteristics of the respective methods stored in InnoFox. To be able to match the InnoFox methods recommendations as precisely as possible with the respective situation or with users' needs only the criteria of the system of objectives, operation system, and system of objects entered by the users for characterization of their specific application cases are considered. In this way it is possible to include in the evaluation of methods the targets envisaged by users during method application, the users' current action situation and resources and the document type to be developed.

For all methods stored in the methods data base, the calculation of a congruent value, each time the InnoFox is used, is done in accordance with the schema shown in Figure 5 [Albers et al. 2014d]:

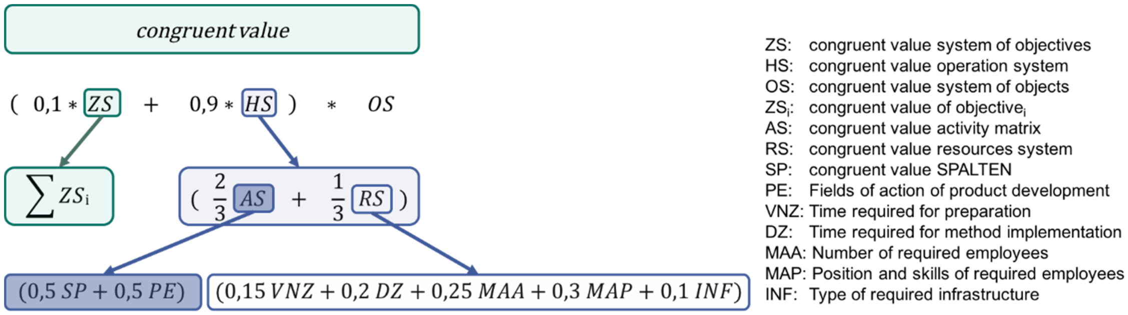


**Figure 5. Calculation of the congruent value for InnoFox methods**

The partial congruent value of the *object system* can only attain values 0 or 1 and is multiplied by the congruent value of a method. This means that within the calculation of the congruent value methods are considered to be either suitable or unsuitable for generating the objects desired by the users.

The partial congruent value of the *system of objectives* indicates the degree to which a method is suitable for achieving the selected targets. The partial congruent value of the operation system defines the suitability of methods for application situations under the restrictions of the respective resources.

The partial congruent value of the operation system relies on the resource and the activity matrix. The value of the resource system states in how far methods can at all be carried out considering the respective resources. Methods in the resource system, for instance, are rated worse if they demand more time or staff than are available in the respective application case. The partial congruent value of the operation system represents the suitability of a method for the users' action situations. A situation can be represented both by a single field in the activity matrix e.g., by the analysis of implications within the activity of idea detection and by a cluster of single activities e.g., by the overall validation throughout all SPALTEN activities described in Section 2.2. By selecting the respective matrix fields, users hence are enabled to describe their situations within the PDP as precisely as possible with just a fewclicks and to receive best suited method suggestions. To make the iPeM-based logic accessible to each user group, an interactive question dialog was developed in addition. This dialog makes it easier for the user to allocate the respective application case to the iPeM matrix fields.

The entire interactive access element has been tested and improved continuously together with the project partners within interviews and workshops by analyzing, for real application cases, how far methods recommendations made by InnoFox correspond to the expectations in terms of method application and to the project partners' expert assessment of application cases. On that basis, both the structural design of the benefit analysis and the significance of the weighting factors were adapted through several iterations.

### 4.3 Synthesis of results in the InnoFox virtual methods coach

This section introduces the individual functions of InnoFox. Figure 6 (left) depicts the possibility of evaluating situations either directly through activities in the iPeM (1 in Figure 6) or through the interactive question dialog (2). Moreover, the criteria of the targets (3) described in Section 4.1 as well as resources (5) can be specified. In addition, it is possible to define the type of object system (4) to be developed. Based on the selection made, the methods are recommended dynamically (6). The possibility of specifying search results by defining the available resources is shown on the right.


**Figure 6. InnoFox – (left) evaluation of situations, (right) specification of resources**

Since the different methods are suited for different activities combinations may make sense and methods building on one another within the respective action field may be chosen. Whereas, within the action field "idea detection", it is useful, for example, to support the activity for generating "alternative solutions" by the method "brainwriting pool". The activity "solution selection" can be supported by the method "pairwise comparison". The respective features are shown in Figure 7 on the left side. On the right, the "community platform" method is outlined by presenting a method profile. By means of an online enter function, also newly developed methods can thus be completed.

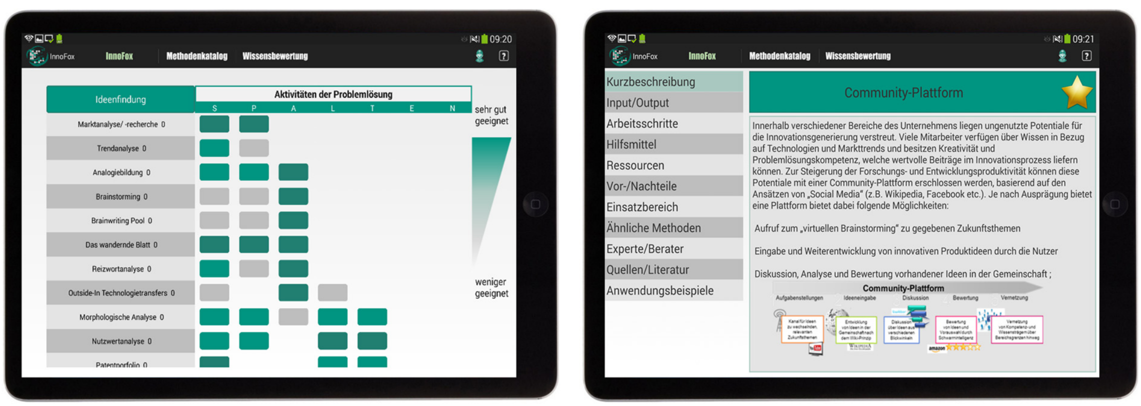


**Figure 7. InnoFox – (left) combining methods, (right) method profile**

Using a beta version, InnoFox was validated by 41 master's students within the project "integrated product development". Based on a task provided by a project partner from industry the students went through the product development process from product profile to fully functional prototypes with the objective of developing innovative solutions.

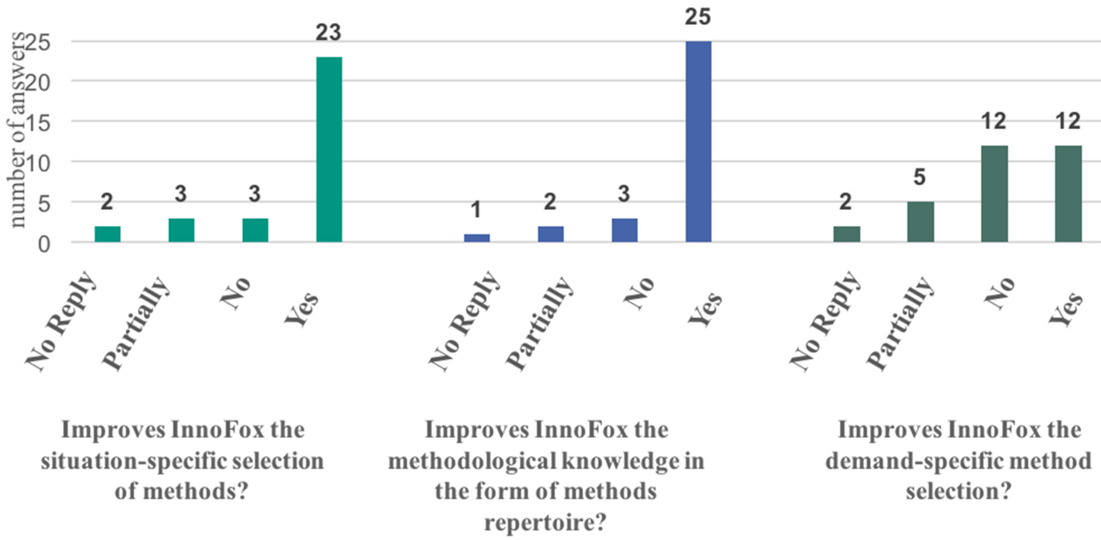


**Figure 8. Results of validation within the integrated product development project**

The objective of the validation, among others, was to find out whether InnoFox improves the users' repertoire and situation and demand specific selection of methods. 30 out of the 41 students were found to have used the application regularly. As is shown in Figure 8, a high proportion of the students says that method knowledge (25) has been improved. In addition, InnoFox compared to printed method collections was found to lead to clear improvements in the situation-specific selection of methods (23). The students interviewed said that through improvements in method selection and method knowledge InnoFox has increased both method application and acceptance within the project.

## 5. Conclusion and outlook

In line with the current state of research as well as with the results of interviews and analyses it is an important objective of methods research to provide users with adequate new methods suiting specific demands. Particularly in the context of agile processes these methods should be structured modularly.

Additionaly the project partners in IN² articulated the need to adapt development methods for virtual product development teams consisting of team members from around the world. Future research should therefore focus on not only the recommendation of suitable methods for specific situations but also on the adaption of thoses methods to specific environments.

First studies have shown that the multimedia preparation of method content in videos has great potental. In view of these findings an interactive application for mobiledevices was developed within IN² enabling users to obtain the details characterizing their specific situation and to receive hands-on, tailor-made methods recommendations. A first study carried out by student development teams proves the additional value of InnoFox in particular as regards the extension of the repertoire of methods and the selection of methods in accordance with specific situations. Due to these successful results the application will be made part of teaching programs. In addition an App will be launched on the market and the InnoFox software will be combined with advisory services.

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Albert Albers, Prof. Dr.-Ing. Dr. h. c.
Karlsruhe Institute of Technology, IPEK Institute of Product Engineering
Kaiserstr. 10, 76131 Karlsruhe, Germany
Email: sekretariat@ipek.kit.edu