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Enabling Distributed Teams – A Process Model for Early and Continuous Method Validation

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Abstract

Neglecting challenges of distributed collaboration can lead to significant efficiency and effectiveness losses in agile, distributed development teams. The EDiT method provides support for improving distributed collaboration of development teams. To ensure acceptance, applicability, and contribution to success in industrial development practice, it is necessary to validate the EDiT method. The goal of this contribution is the development of a process model for early and incremental validation of the EDiT method in the field finally leading to a validation of the EDiT method itself.

Keywords: distributed design, design teams, teamwork, agile development, process improvement

1. Introduction

To develop advanced systems interdisciplinary and to face the growing complexity in product development processes, agile, and, above all, distributed development teams are one approach to face these challenges (Dumitrescu *et al.*, 2021). The shift towards distributed teams is additionally accelerated by the Corona pandemic and the associated work in the home office (Garnadt *et al.*, 2020). Distributed product development often poses significant challenges to development teams (Larsson *et al.*, 2003). Representing a way to overcome these challenges, many methods and tools are already available to support the development process (Graner and Behr, 2012). Among them are for example the VDx Guidelines based on design theories by e.g. Pahl *et al.* (2007) or the Integrated Product Development approach by |Ehrlenspiel and Meerkamm (2017). The use of development methods has an empirically proven positive effect on organizational performance (Vajna and Kittel, 2009). However, methodological support for identifying and tapping improvement potentials of distributed collaboration in development teams does not yet exist (Bavendiek *et al.*, 2016). Due to the existing need for research, Duehr et al. (2021c) is developing the EDiT method (Enabling Distributed Teams). This user-oriented method addresses the continuous improvement of distributed collaboration in development teams. To enable acceptance, applicability, as well as an additional benefit of the method in development practice, the advantages of early and continuous validation of technical systems (Albers et al., 2016a), need to be taken into account when validating the EDiT method. Appropriate frameworks for method validation addressing the special development situation of distributed teams are needed for this purpose.

2. State of research

2.1. Agile product development

To be able to model an individual product development process appropriately, the use of iterative approaches in product development is becoming increasingly more common. Thus, the iterative

character of product development is described in the extended system triple of product engineering by a continuous interaction of three systems: the system of objectives and the system of objects evolve iteratively through interaction with the operation system during the product development process. (Albers et al., 2016a) One method to enable this continuous development is the problem-solving method SPALTEN. The SPALTEN methodology describes a universal approach for handling problems with different boundary conditions and degrees of complexity represented by activities in a specific structure or sequence: situation analysis (S), problem containment (P), detection of alternative solutions (A), selection of solutions (L), analysis of consequences (T), deciding and implementing (E) and recapitulate and learn (N). SPALTEN thereby is a German acronym. (Albers *et al.*, 2016b)
Product development as a set of many problem-solving processes requires a high level of collaboration, coordination, and communication. As a result, the use of agile approaches from software development is becoming increasingly important in mechatronic product development. The basis of an agile approach is the empirical process control, which divides the development process into comparable short control loops through the pillars of transparency, verification, and adaptation (Schwaber, K., Sutherland, J., 2020). That iterative-incremental approach, such as proposed by the Scrum framework, allows flexibility to respond to the unexpected. This flexibility is especially needed in modular product development, where high planning uncertainty caused by complexity is dominant (Bursac, 2016).

2.2. Distributed Collaboration in Agile Product Development

In a survey of over 40,000 agile experts in 2020, 81% state that agile distributed development teams exist in their organization (digital.ai, 2020). In this contribution, distributed product development refers to the development of new product generations in which the development team carries out product development activities jointly and from geographically separate locations (Duehr *et al.*, 2019). In addition to opportunities such as the pooling of company-wide expertise, distributed collaboration confronts development teams with significant challenges. The use of an agile way of working generally has a beneficial effect on overcoming these challenges (Duehr *et al.*, 2021a)**.** However, significant challenges to distributed collaboration often remain. These need to be addressed to avoid overburdening team members and loss of efficiency and effectiveness in distributed product development processes (Duehr *et al.*, 2020). The targeted use of methodical support is suitable for such a purpose (Graner and Behr, 2012). One potentially suitable development method is the user-oriented EDiT (Enabling Distributed Teams) method, which addresses the continuous improvement of distributed collaboration (Duehr *et al.*, 2021c). The extensive description of the objectives of the EDiT method is specified by 16 requirements (Duehr *et al.*, 2021c). The EDiT method is represented by four consecutive phases: potential analysis, measure definition, measure implementation, and measure evaluation. The different phases with their activities can be carried out iteratively employing various possibilities of implementation such as workshops, interviews, and surveys. The EDiT method is based on the fields of action of distributed product development with their descriptive influencing factors (Albers *et al.*, 2020; Duehr *et al.*, 2021b). Since no comprehensive validation of the EDiT method has yet been carried out, especially field studies should be focussed on in the following validation activities.

2.3. Validation of development methods

For decades, various authors have been criticizing inadequate or even lack of validation of methods in developmental methodology research. Among the critics are Zanker (1999), Cantamessa (2003), Blessing and Chakrabarti (2009), Andreasen (2010), Marxen (2014), and Üreten et al. (2020). For example in the study by Cantamessa (2003), 718 publications of the ICED conferences from 1997 and 1999 have been analyzed. Most of the publications included the development of new methods and tools, while only a few of the conference papers dealt with validation. Furthermore, only 37.5% of the publications of newly developed methods and tools addressed general issues regarding implementation in an industrial setting. (Cantamessa, 2003) In addition, Blessing and Chakrabarti (2009) criticize a lack of detailing of validations performed. At the same time, high requirements for the quality of validation studies are raised (Himme, 2007). As a central activity in the research process, some frameworks as well as numerous methods of data collection and analysis already support

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validation. Nevertheless, frameworks such as the DRM (Blessing and Chakrabarti, 2009) or Validation Square (Pedersen *et al.*, 2000) do not target to provide method developers with sufficient concrete procedures for validation. Emerging research approaches such as the Concept Map (Üreten *et al.*, 2019) do not yet address the iterative nature of validating and refining methods. Critical to the acceptance of development methods in practice is ensuring a high level of external validity. The validation environment of the field ensures such a high external validity and thus a high transferability of the results into practice. In addition, validation in the field provides the method developer with direct insights into the existing mindsets, tools as well as the task spectrum of the developers. (Blessing and Chakrabarti, 2009) However, there is a particular lack of validation studies in industrial development practice. One possible reason for the lack of validation studies in the field is the significant challenges in conducting field studies. For one, attributes are difficult to control, which can subject results to further influences (Marxen, 2014). For another, validation in industrial development practice can be associated with significant cost and time for method developers as well as other participants in the validation study, if applicable (Blessing and Chakrabarti, 2009). Consequently, the validation of development methods in the field is not yet sufficiently and consistently methodically supported from today's point of view.

3. Aim of research and methodology

The EDiT method provides methodological support for improving distributed collaboration of development teams. To ensure acceptance, applicability as well as a contribution to success of the method in industrial development practice, it is necessary to validate and further develop the EDiT method early and continuously especially in the field. Frameworks such as the DRM (Blessing and Chakrabarti, 2009) or the Concept Map (Üreten *et al.*, 2019) do not target the support of method developers with a sufficiently concrete procedure for validating development methods focussing distributed teams.

To substantiate the identified need for research, a preliminary study was carried out. Here, 24 members of the research project MoSyS[1] as well as of the technical committee of the VDI[2] were asked by their agreement to the following statements using an online questionnaire (cf. Figure 1).

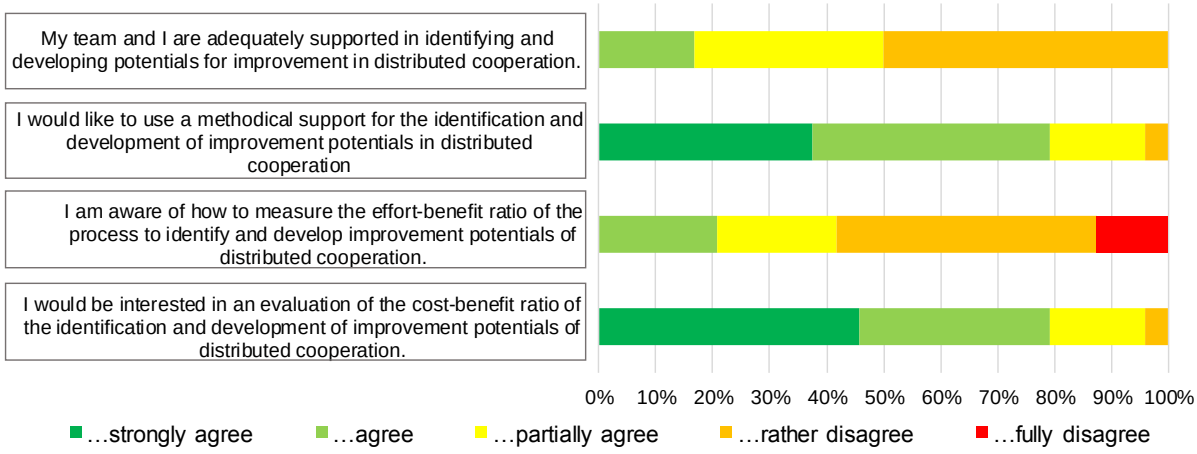

Figure 1. Evaluation of the need for research

As can be seen in Figure 1, the experts' assessments confirm that methodological support is needed to improve distributed collaboration because of the insufficient support and the willingness to use

[1] The German acronym "MoSyS" is short for "Human-Oriented Design of Complex Systems of Systems". This research project funded by the German Federal Ministry of Education and Research (BMBF) aims the development of new methods, aids and IT tools for engineering.

[2] The Association of German Engineers (VDI) is a network of engineers of all disciplines in all professional functions and the largest technical-scientific association in Germany.

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methodical support. In addition, there is an interest in the effort-benefit ratio when improving distributed collaboration, which is an essential aspect of validation. At the same time, the respondents are faced with challenges when investigating the effort-benefit ratio. In summary, there is a need for a support for early and incremental validation of the EDiT method in the field. Accordingly, the following objective was derived for this work:

This work aims to develop and apply a process model for the early and incremental validation of the EDiT method in a field study regarding its applicability and its contribution to success.

Based on the identified need for research and the objective, the following research questions were derived to structure the research project:

- What are the requirements for early and incremental validation of the EDiT method in industrial development practice?
- How can the EDiT method be validated in a field study regarding its applicability and its contribution to success?
- What contribution can the use of the developed process model provide to validate the EDiT method in agile development practice using the example of a machine tool manufacturer?

To answer the research questions, the approach of the Design Research Methodology (DRM) according to Blessing and Chakrabarti (2009) has proven itself in technology-oriented research. First, the requirements for early and incremental validation are determined in an initial descriptive study based on a systematic literature research. Subsequently, a process model is developed in a prescriptive study. Finally, the contribution of the developed process model is evaluated in a second descriptive study.

A known machine tool manufacturer serves as the research environment for the early validation of the approach. In this, an agile, distributed development team of 11 people is accompanied, which was assessed to be a suitable validation environment for the EDiT method. Specifically, the accompanied people who work on the derivation of two machines from a modular system, are distributed over two development sites. In addition, due to the Corona pandemic at the time of the validation study, the team members worked together from their home offices. The team already has a variety of tools at its disposal to support collaboration. Examples include Microsoft Teams as a communication tool, Jira for task planning and management, and Confluence as a knowledge database. In addition, the research project MoSyS and the VDI's Agile Development of Mechatronic Systems expert committee were consulted for the transferability of the approach.

4. Analysis of the requirements for early and incremental validation

To contribute to the confirmed need for research, the requirements for a process model for early and incremental validation of the EDiT method in the field were analysed as part of the descriptive study I. Literature from the years 2000 - 2020 that corresponded to one of the following three clusters of literature was considered: Literature on aspects of existing frameworks of validation; Literature on aspects of validation in field studies; Literature on aspects of the acceptance of methods in development practice.

In total, seven requirements have been identified that need to be addressed in a process model that supports the validation of the EDiT method in the field. A process model for early and incremental validation of the EDiT method in the field needs to support:

- the evaluation of the applicability of the EDiT method
- the evaluation of the contribution to success of the EDiT method
- the examination of the suitability of the underlying challenges in the company
- the enabling of statements regarding the internal and external validity, the reliability as well as the objectivity of the results
- the guarantee of comparability of conducted studies
- the iterative application possibility of the process model
- the enabling of a suitable selection of measurable variables to validate the success of the method

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5. Process model for the early and incremental validation of the EDiT method in the field

Answering the second research question, how the EDiT method can be validated in a field study regarding its applicability and its contribution to success, the requirements were addressed by developing a process model that supports early and incremental validation of the EDiT method. The resulting process model is based on the model-theoretical framework of the extended system triple of product engineering, in which the elements of validation and further development were classified following Albers et al. (2016a). The developed process model for the validation of the EDiT method in industrial development practice is shown in Figure 2.

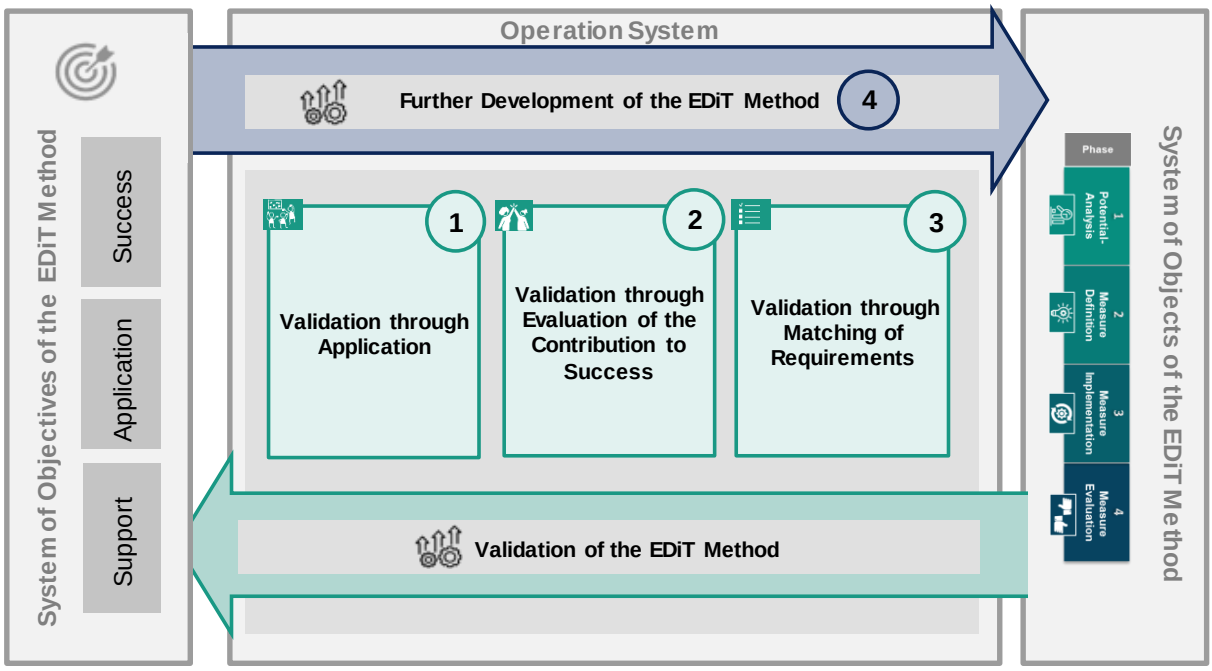

Figure 2. Process model for validating the EDiT method in the field

The process model describes how the validation and further development of the EDiT method can take place iteratively as an interaction of the system of objects with the system of objectives via the operation system. The validation of the applicability as well as the contribution to success of the EDiT method is carried out in four categories within the operation system in the framework of the process model. The first category, *validation through application*, includes the choice of application type, the review of improvement potential, the application of the EDiT method along with its four phases as well as the documentation of resources.

In the second category, *validation through evaluation of the contribution to success*, the operationalization of the method performance plays a central role. Consequently, the identification and selection of appropriate metrics to evaluate the success of the EDiT method are supported with guidelines and examples. For this purpose, qualitative and quantitative, subjective and objective variables for measuring the usefulness, the effort as well as the implementation of the EDiT method are exemplified. Five criteria are defined for the selection of suitable measurable variables. For example, the criterion of "ensuring the meaningfulness of a measurable variable regarding the influence of interfering variables" can be mentioned here. Furthermore, possibilities for collecting data of distributed collaboration in the field are pointed out. For example, the analysis of project management software, the use of eye-tracking technologies, or the use of stopwatches in the context of participant observation can be listed.

The third category, *validation through comparison of requirements*, represents a comparative element within different company-specific validation studies. The category includes the comparison of the requirements for the support performance, the applicability, and the contribution to success of the EDiT method with the insights gained during the application of the EDiT method (Duehr *et al.*, 2021c). For

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this purpose, the degree of fulfilment of the requirements is surveyed. This can be evaluated by the method researcher or the development team, depending on the degree of insight gained during the application of the EDiT method.
Lastly, recommendations for the *further development of the EDiT* method can be derived from the insights of all three validation categories.

6. Application of the process model for validation using the example of a machine tool manufacturer

To answer the third research question, a second descriptive study was conducted. The aim was to determine the contribution of the developed process model to the validation of the EDiT method in terms of its applicability and contribution to success in the field. To answer this research question, a case study was conducted in a development team at TRUMPF GmbH & Co. KG. The results are presented according to the four categories of the process model's operation system (cf. Figure 2).

6.1. Validation results of the case study

6.1.1. Validation through application

As part of the first category of the process model, the EDiT method was applied. For example, in the first phase of the EDiT method, workshops, as well as a retrospective with targeted questions and discussions, were used to identify challenges of the distributed collaboration of the development team. In phases 2 and 3, the team defined individual measures in a retrospective and implemented them. In the last phase of the method, the team evaluated the measures in retrospectives and continuously transferred their knowledge regarding the method results to other teams or team members (cf. Figure 3).

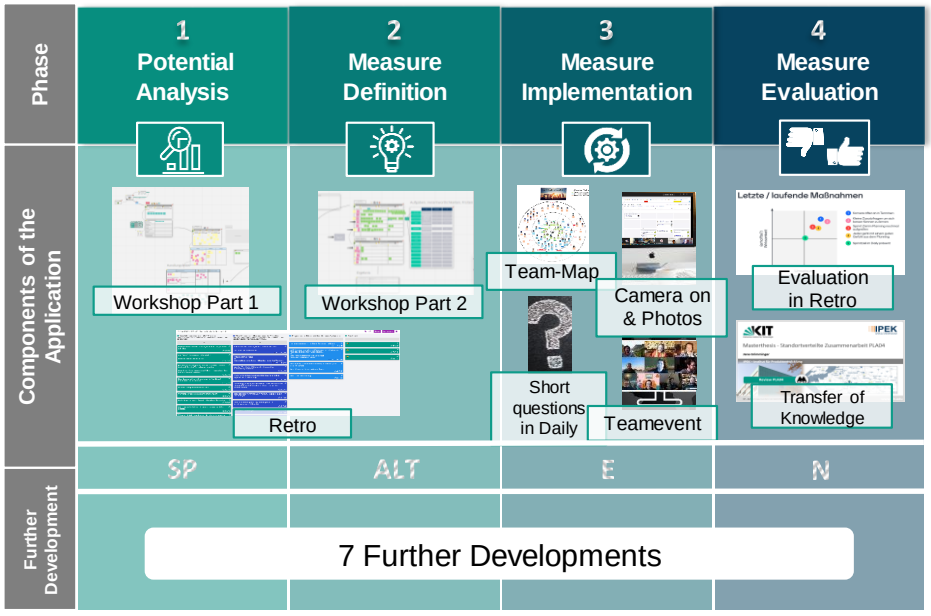

Figure 3. Implementation along with the four phases and further development of the EDiT method at TRUMPF

6.1.2. Validation through the evaluation of the contribution to success

According to the developed process model, measurable variables were identified for evaluating the usefulness of the EDiT method, the effort of implementing the measures of the EDiT method, and for assessing the actual implementation of measures within the framework of the EDiT method. As shown in Figure 4, this included identifying both objective and subjective measurable variables for each measurement category, as well as quantitative and qualitative measurable variables.

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Benefit	Effort	Implementation
	Quantitative	Qualitative
Objective	e.g. number of delays in the Daily meeting	e.g. change from "Siezen" to "Duzen"
Subjective	e.g. assessment of working atmosphere by team members	e.g. quote: "there is significantly more collaboration"

Figure 4. Potential measurable variables of measure benefit, effort, and implementation

The quantifiable variables of the implementation of the measures, the effort as well as the usefulness were analysed. In the third phase, *measure implementation*, of the EDiT method, the field of action *team development* was addressed. Figure 5 shows the success of the implementation of measures to improve team development by analysing the event of the Team Daily.

Figure 5. Analysis of the measurable variables for the evaluation of team development in the Daily: reduced silence time and increased moments of laughter

It was observed that the measure of the "daily personal short question" defined during the EDiT method was implemented daily. In addition, it was surveyed that 67 percent of the team members turned on their video in the Daily to implement the defined measures to achieve more face-to-face interaction. The implementation of the measures caused a daily effort of 3 min and 28 seconds on average, mainly caused by answering the daily short question. Benefits were achieved in the form of a significant increase in the number of moments of laughter as well as a significant reduction in the amount of time spent in silence, which represents a positive development within the team as both variables are known for their influence on team development. Those benefits can be attributed to the EDiT method due to the implementation of the defined measures that essentially took place. Since the implementation of the measures took place voluntarily, the effort involved can be considered acceptable. Thus, the evaluation of the contribution to success showed the success of the EDiT method based on a significant improvement of the new state compared to the baseline condition of the team development. The achieved success of the implementation and further development of the EDiT method must be compared to an effort of 92 hours. This effort is considered reasonable in the context of this work.

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6.1.3. Validation through matching of requirements

In this category, the 16 requirements for the EDiT method identified by Duehr et al. (2021c) were matched with the experiences and impressions of the implementation of the EDiT method in the case study. In doing so, the 16 requirements for the EDiT method are divided into requirements for its supporting performance, requirements for its applicability, and requirements for the EDiT method's contribution to success (Duehr *et al.*, 2021c). Thus, an evaluation of the EDiT method could be made independent of the individually identified potential for improvement as well as the measures taken in the validation environment. For example, in addition to showing success based on measurable variables, success could be demonstrated by matching the requirements to the contribution to success of the EDiT method. This was done using a survey of the team members regarding their agreement with the fulfilment of the requirements by the EDiT method in the form of a five-point Likert scale. An excerpt of the results is shown in Figure 6. Thus, the participants in the survey essentially agreed with the requirements for the contribution to success of the EDiT method.

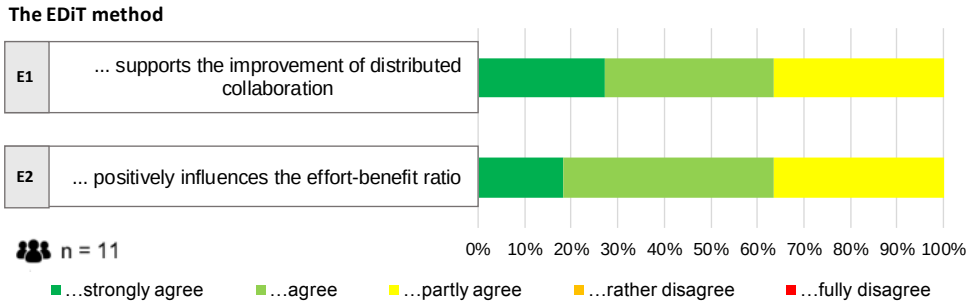

Figure 6. Analysis of the degree of fulfilment of the requirements of the EDiT method

6.1.4. Further development of the EDiT method

As part of the fourth category of the process model, seven components of the system of objects of the EDiT method were further developed towards the defined system of objectives during the application of the EDiT method at TRUMPF:

- The conception of a two-part workshop for the virtual application of the EDiT method
- The restructuring and naming of the fields of action and influencing factors of distributed collaboration resulting from phase 1 of the EDiT method
- The design of a procedure for the implementation of phases 1 and 2 in a retrospective
- The addition of phase 3 - *implementation of measures* - as a further phase of the EDiT method
- The naming of the method as "EDiT Method - Enabling Distributed Teams"
- The development of six success factors for the definition and implementation of measures
- The conception of fundamental components of phase 4 - *measure evaluation*

6.2. Evaluation of the process model

The process model was evaluated based on the seven requirements identified for a process model for early and incremental validation of development methods in the field by the method researcher that applied the EDiT method in the case study (cf. chap. 4). It was concluded that the developed process model addresses all seven requirements. However, limitations in the validation in the field were found. For example, difficulties exist in collecting an appropriate amount of data to measure the baseline condition. In addition, interfering variables that exist in the field continue to have a significant impact on the validation results. Furthermore, the existing limitations of the results were discussed based on the quality criteria of empirical studies, validity, reliability, and objectivity. For example, the internal validity of the validation results is limited. Thus, it could not be clearly determined whether the identified improvement of the new state resulted exclusively from the application of the EDiT method as well as the implementation of derived measures. Consequently, it could be shown that the application of the developed process model contributes to the validation and further development of the EDiT method in the field.

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Further insights gained through the application of the process model are that the EDiT method can bring great added value, especially for inexperienced teams, due to the simple and quickly possible iterative application of the EDiT method without requiring a great amount of prior knowledge. Furthermore, the discussion of the process model shows that there is a need for further activities to sharpen the understanding of validation since the further development of the EDiT method through validation is often not seen as an outcome of validation.

7. Conclusion and outlook

After an initial confirmation of the research needs, seven requirements for early and incremental validation of the EDiT method in the field were identified. These requirements were considered and implemented in the development of the process model. To evaluate the process model, it was applied to validate the EDiT method in two case studies.
By applying the process model, the following results during the validation of the EDiT method were achieved:

- A total of 13 components of the system of objects and the system of objectives of the method were further developed through the early and incremental validation of the EDiT method.
- Two initial guidelines for the application of the EDiT method in practice now exist in two different variants.
- The initial validation of the applicability of the EDiT method was carried out successfully.
- The initial validation of the contribution to success of the EDiT method was carried out successfully.

An evaluation of the process model confirmed that all seven requirements are largely met by the developed process model. Nevertheless, there are still some limitations and potentials for further development of the process model. Therefore, further studies should focus on applying the process model in more field studies e.g. investigating interfering variables of field studies and the impact on the process model. Based on that, the process model should be further developed iteratively. Finally, a transfer of the process model for the validation of other development methods should be aimed for.

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