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Procedia CIRP 00 (2024) 000–000

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57th CIRP Conference on Manufacturing Systems 2024 (CMS 2024)

Towards a Change-Specific and Company-Individual Manufacturing Change Management

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Abstract

Manufacturing companies are challenged by various influencing factors in the volatile environment, which requires frequent adjustments to their factories, known as Manufacturing Changes (MCs). The wide variety of changes and the company-individual implementation of Manufacturing Change Management (MCM) processes in practice represent a significant challenge for research, as general approaches are often too rigid and cannot be adequately integrated into the individual structures of companies. Existing MCM processes in the industry often lack flexibility, methodological, and digital support. This contribution proposes a change-specific and company-individual approach to address these challenges. The four-step methodology includes steps for describing MCM processes, creating a systematic change description model, identifying and structuring methods and digital tools, and correlating attributes through a Delphi study. An overall application methodology supports companies in using the methodology and serves as a basis for the final validation.

Keywords: Concept; Change Management; Methods; Digital Tools; Process Flexibility

1. Introduction

Manufacturing companies face a wide range of external and internal challenges. This volatile environment [1] is illustrated by various current events, such as the shortage of gas supply due to sanctions against Russia following the war in Ukraine [2], the emergence of generative artificial intelligence, or the increasing shortage of skilled workers [3]. To respond to these and many other events or trends, companies must continuously make changes to their factory [4]. These so-called Manufacturing Changes (MCs) are defined as “any alteration made to the factory or its elements” [5]. MCs can "be of any size or type, can involve any number of people, and take any length of time” [5]. MCs that occur in practice can, therefore, differ significantly in their characteristics, for example, parameter changes to machines and changes to the entire factory layout are both defined as MCs. A study by Rammo & Graf [6] shows that, in addition to the large number of MCs, this wide variety of different types of changes poses a significant challenge to manufacturing companies, as different changes afford different handling.

This handling of MCs is referred to as Manufacturing Change Management (MCM). A large number of manufacturing companies have a defined process for MCM [7]. While there are some generalized processes in research [5], such processes in industrial application are usually adapted to the individual requirements and circumstances of the companies and, therefore, differ from company to company, e.g., in terms of the number of process steps, the number of different roles, or the number of documents used.

Due to this individual design of MCM processes in different companies, many challenges in the application of these processes can only be solved to a limited extent with the generalized approaches available in the literature [8]. The difficulty of developing an approach that can be adapted to the company-individual processes and simultaneously considering and modeling the large variety of MCs is a significant challenge in MCM research. To address this, this contribution proposes a concept of a change-specific and company-individual approach to support MCM processes.

The remainder of this contribution is structured as follows. Section two introduces key challenges in applying MCM in industrial practice. Section three discusses existing approaches to these challenges and their shortcomings. In the following section, the proposed concept is described. Section five provides a discussion and an agenda for future research. Finally, section six summarizes the entire article.

2. Current challenges in MCM

The application of MCM processes is widespread in industrial practice [7]. However, many manufacturing companies encounter several challenges during the application. The study by Rammo & Graf [6] identifies three main challenges in the application of MCM processes in industrial practice.

2.1. Process flexibility

The first challenge identified is the flexibility of MCM processes. To optimize internal procedures, MCM processes in companies are standardized and stored in the corresponding company process management. To control the complexity of MCM, a structured and standardized approach is generally desirable [9]. Still, companies should be flexible in dealing with each individual change to avoid unnecessary effort [8]. The variety of changes can rarely be handled by a consistently standardized solution [10], which often presents manufacturing companies with the challenge of applying their standardized process to a specific change and determining which process steps are necessary for a particular MC.

2.2. Selection of suitable methods

Another relevant challenge is the selection of suitable methods to support the MCM process. Clarke & Manton identify methods as a key factor in the effectiveness of successful change management [11]. According to Ehrlenspiel & Meerkamm, the frequency with which methods are used will likely continue to rise due to increasing complexity and time pressure [12]. The variety of changes and methods complicates the selection process for suitable methods. Certain methods are only suitable for certain types of changes and in certain process steps [5]. For example, time-consuming methods such as value stream mapping are unsuitable for minor changes such as adjusting machine parameters. The correct selection of methods poses challenges for manufacturing companies.

2.3. Selection of suitable digital tools

Closely related to the methodological support is the third challenge in industrial practice, the digital support of the MCM process. In particular, using digital tools to support the MCM process is seen as a promising measure [6]. Digital tools offer great potential when used in business processes [13] and also in MCM [14]. However, selecting the right digital tools for the processes is challenging [15]. Similar to the methods, there is now a wide range of digital tools that have to be mapped to the wide variety of changes. Selecting the right digital tools for certain changes and in certain process steps is a challenge since digital tools are usually associated with an investment, which further increases the need for successful use.

3. Existing approaches and shortcomings

In the literature, various works have dealt with the three challenges mentioned. Since most publications address only one of the challenges, the publications and shortcomings below are sorted by the respective challenge.

3.1. Process flexibility

Although the need for flexibility in change management has been recognized by various authors [5,16], few concrete approaches exist in the literature. An early approach in the field of product changes, also referred to as Engineering Change Management (ECM), is presented by Jaratt et al., who use change classes to adopt the process [17]. However, they limit their process flexibility to iterations and parallelizations, and the abstract phases provide only very rough recommendations for action but no concrete steps for companies. Koch makes a first fundamental contribution in terms of flexibility from the perspective of MCM processes [5]. A comprehensive general MCM process is developed and adapted based on the three change categories standard, optional, and extended with regard to the necessary steps, deliverables, and roles. However, this approach provides little flexibility, as only three change types are distinguished. A more detailed approach is taken by Haghi et al. [10] and Sippl et al. [18], who use ten change characteristics or flexibility factors to adapt a general MCM process.

The existing publications in the literature on the flexibilization of MCM processes show various shortcomings. Although the flexibilization of the MCM process is addressed in a handful of publications, often only a few types of changes are differentiated, which does not cover the broad spectrum of changes in manufacturing companies. Therefore, no concrete recommendations for action can be derived. Furthermore, all of the approaches mentioned refer to general, usually purely literature-based processes that are flexibly adapted. As many companies already have individual processes in place, it is challenging to integrate the approaches in practice. Only Sippl et al. provide an approach for integrating individual company steps into the general process [18]. However, the basis of flexibilization remains the general process, which requires a renewed transfer of the results of the approach into the company structures.

3.2. Selection of suitable methods

In the area of methods in change management, Assmann shows an approach for selecting methods in terms of their level of detail based on the scope of the changes [16]. He focuses on methods of the product development process and divides changes into three classes. Tavcar & Duhovnik provide another approach from the area of product changes, focusing on methods supporting knowledge retention along the ECM process and naming methods with structured documentation, such as FMEA or 8D reports [19]. However, the total number of methods proposed is small. Koch gives an initial overview of methods in MCM and then assigns them to phases of the change process [5]. Within the phases, the methods are then assigned according to their suitability for individual activities. However, a change-specific selection of methods is not part of the approach. Various studies on available methods also exist in other domains, such as quality management [20] or project management [21].

The literature on methods in MCM shows several shortcomings. Although there are initial collections of methods to be used in MCM, there is no change-specific selection of methods in the MCM process. The selection of appropriate methods, however, depends heavily on the change to be managed. In addition, only a few approaches assign methods to specific process steps. However, these few approaches for method assignment are based on general literature-based processes. The possibility of transferring these to company-individual MCM processes is neglected.

3.3. Selection of suitable digital tools

In the area of digital tools, Gollmann et al. examine which IT systems, such as Enterprise Resource Planning, can be used in the ECM process [22]. They limit themselves to a small number of IT systems and assign them to rough phases of the ECM process. Aurich & Rößing examine the use of Virtual Reality (VR) in change impact analysis [23]. The aim is to illustrate relationships between individual elements of the factory to better analyze and predict change propagation. However, they only consider a specific step in the change process, the change impact analysis, and not the entire process. Siedler et al. consider the entire process in terms of a VR/Augmented Reality (AR) application [24]. They identify the capabilities of VR/AR and map these with the requirements of the steps in the MCM process, from which recommendations can be derived for using VR/AR in the process.

Digital tools in MCM have not yet been well-researched compared to other domains. There is no comprehensive collection of digital tools and only isolated assignments to process steps, usually only for a specific tool. Similar to the methods, the approaches with digital tools are also limited to assigning them to general process steps without considering the possibility of transferring them to company-individual MCM processes. A change-specific selection of suitable digital tools is also not addressed in any publication.

The deficits show that the existing approaches in the literature do not adequately address the three challenges. Especially the change-specific and company-individual approaches to these challenges have not yet been sufficiently researched in the literature. For this reason, this contribution will present a change-specific and company-individual approach to support MCM processes with regard to the three challenges: process flexibility, the selection of best-suited methods, and the selection of best-suited digital tools.

4. Concept for a change-specific and company-individual Manufacturing Change Management

The concept presented in this contribution addresses the three challenges of process flexibility, digital and methodological support considering change-specific requirements, and company-individual structures. The approach intends to help change managers, planners, and others involved in MCs implement changes more effectively and efficiently. The approach is designed for all manufacturing companies, regardless of size or industry. As the approach uses the existing MCM process in the respective companies, an MCM process should already be in place. Otherwise, the approach can also be applied using an MCM process from the literature.

The concept is divided into four steps (Figure 1), each producing a scientific result and a user method for utilizing these scientific results. In step 1, attributes that describe the activities in the individual steps of the MCM process are identified. In addition, information that emerges in these process steps is collected. In step 2, attributes for describing changes are identified, and the emerging information from step 1 is used to derive company-individual iteration steps, i.e., how often and when the change description needs to be adapted to the newly available information. In step 3, methods and digital tools are first identified and structured. Attributes for the description of methods and tools are then developed. Step 1-3 are structured similarly, each involving identifying and structuring descriptive attributes. In step 4, all attributes are then correlated with each other, and an algorithm for the calculation of the output matrix is developed. The overall application methodology is also designed.

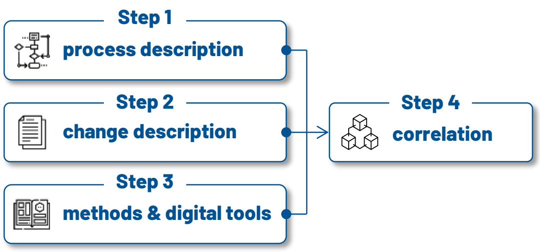

Figure 1: Overview of the steps

4.1. Step 1: Process description

The first step of the concept incorporates the identification of process attributes (PAs) and process information (PIs). Since the methodology is intended to use the individual MCM processes in companies, it must be ensured that the often very diverse processes in different manufacturing companies can be incorporated in a standardized way. To achieve this, a framework is to be developed with which MCM processes can be uniformly described and thus abstracted. The activities in the individual process steps are to be described using PAs. PAs are divided into general PAs and MCM-specific PAs. General PAs characterize activities independent of the domain. The general PAs (e.g., communication effort) should be evaluated using a scale (e.g., 1-9). MCM-specific PAs (e.g., screening for potential MC) are specific activities in MCM and are assigned to a process step, not rated according to a scale. PAs are initially developed based on the literature. For the general PAs, process or task descriptions from various domains, e.g., cognitive task analysis from psychology or ergonomics, can be used. MCM-specific PAs are mainly derived from MCM processes found in the literature. The developed attributes are then expanded in case studies and verified in expert interviews.

PIs describe emerging process information, i.e., information that arises during the MCM process. Such information could be, for example, the exact costs of the change, which are only known after a cost analysis, or the affected stakeholders, which are only understood after a stakeholder analysis. As this information appears at different points or steps in the MCM process due to the different structuring of the company-individual MCM processes, it is also standardized via the framework, like the PAs, and then assigned to the respective process step. The procedure for identifying these PIs is analogous to the PAs and includes a literature research, case studies, and expert verification. The scientific result is the framework consisting of PAs and PIs.

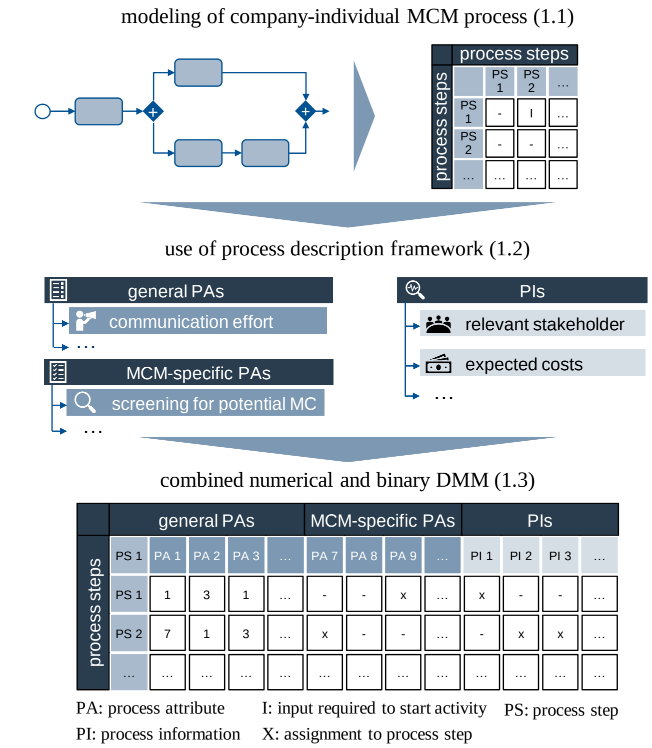

Figure 2: User method of step 1

The application method in step 1 (Figure 2) involves modeling the company-individual process (1.1). The process is represented with a Design Structure Matrix (DSM) for better processing and calculation with the other methodology results. All dependencies of the respective steps must be modeled here. Using the framework developed in this step, the modeled process can be described with the help of PAs and PIs (1.2). This description is also in the form of a matrix, a Domain Modeling Matrix (DMM). A numerical DMM is used for the general PAs, which are evaluated using a scale. A binary DSM is sufficient for the MCM-specific PAs and the PIs, which are only assigned to certain process steps. The result of the user method in this step is a DSM that shows the relationships between the process steps and a combined DMM that assigns PAs and PIs to the process steps (1.3).

4.2. Step 2: Change description

To cover the wide range of MCs and use them as input for the methodology, MCs must be described systematically. Such a description model, which is developed in the step 2, consists of change attributes (CAs) and iteration steps. Iteration steps are necessary because not all information about the change is available at the beginning of the change process in the desired quality to describe or evaluate the change in detail. Therefore, the description model must consider the PIs from step 1 that arise during the process. This is covered by iteration steps of the change evaluation at the points where the PIs occur in the process. As the PIs arise at different points depending on the company, the iteration steps must also be derived individually for each company.

In step 2, CAs are first developed based on literature and experts. Since the CAs are calculated with correlation values, the majority of the CAs must be formulated so that they can be evaluated using a uniform scale (e.g., 1-9). These CAs are then mapped with the PIs from step 1 using a DMM. This matrix shows which PIs are necessary to evaluate certain CAs. The connections are established via an expert workshop. The scientific result is a list of CAs and a CAs/PIs matrix (DMM) with the relationship between CAs and PIs.

From the user's perspective (Figure 3), companies can first select from the general catalog of CAs those that are relevant to the company for evaluating changes (2.1). With this list of relevant CAs, the relevant PIs can be derived using the CAs/PIs matrix (2.2). The company can then determine which PIs from the process it must consider in its description model. The process described in step 1 can then be used to derive the process steps at which an iteration must take place (2.3). These iterations can then also be captured in the form of a matrix (DMM). The result from the user's perspective is a list of the relevant change attributes and a matrix with the iteration steps.

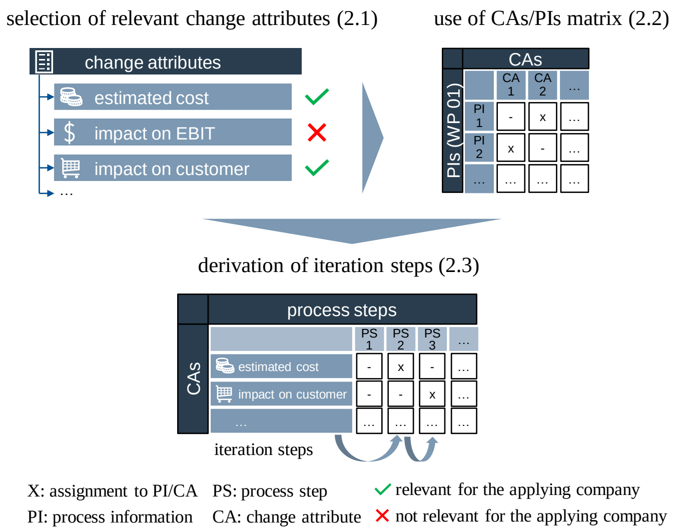

Figure 3: User method of step 2

4.3. Step 3: Methods and digital tools

In step 3, methods and digital tools (M&DT) for the digital and methodological support in MCM processes are identified and described systematically. M&DT are first identified based on a literature research and an online survey. This collection is then structured with the help of fact sheets, verified by experts, and summarized in a catalog. As in step 1 and 2, an abstraction is made through descriptive attributes to ensure the methodology can be adapted and expanded regarding the M&DTs.

These attributes are developed separately for methods and digital tools based on a literature research and expert interviews. These method attributes (MAs) and digital tool attributes (DTAs) are then summarized in a catalog, verified with experts, and applied to the identified M&DTs. Here, too, the attributes should be assessable using a standardized scale (e.g., 1-9). The scientific work result is a catalog with described M&DTs and a catalog with MAs & DTAs.

From the user's perspective, companies can select from the general catalog of M&DT those that are applied or available in the company or those whose applications should be tested (3.1). In addition, company-specific methods or digital tools that are not part of the catalog can be systematically described with the help of the MAs and DTAs and thus added to the catalog (3.2). The result from the user's perspective is a company-individual catalog of described M&DTs, also in the form of a DMM (3.3).

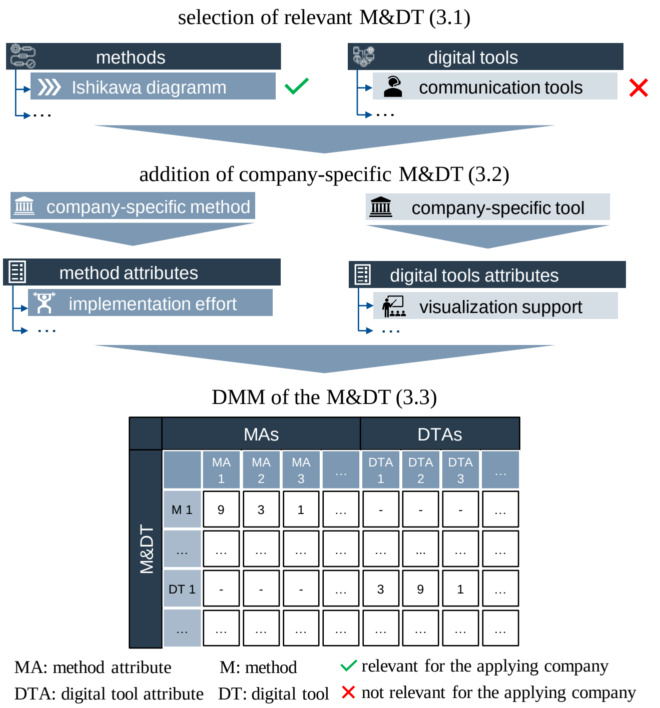

Figure 4: User method of step 3

4.4. Step 4: Correlation and user application method

In step 4, the attributes from the previous steps are correlated (4.1). For this purpose, a separate DMM is created for each of the three interrelationships between PAs, CAs, and MAs or DTAs. MAs & DTs can be combined for the correlation, as the investigation of the interaction between MAs & DTs is not to be investigated. However, a correlation can still be shown via the fact sheets from step 3. The DMMs are filled in as part of an expert-based Delphi study, assigning each pair of values a correlation value. The possible values range from -9 (strong negative correlation) to 9 (strong positive correlation). The matrices resulting from the four steps will be calculated at the end to create a change-specific process with assigned M&DT. For this purpose, an algorithm is developed that calculates the different matrices with each other (4.2). The scientific work results are the DMMs for the correlation and the algorithm for calculating the individual matrices.

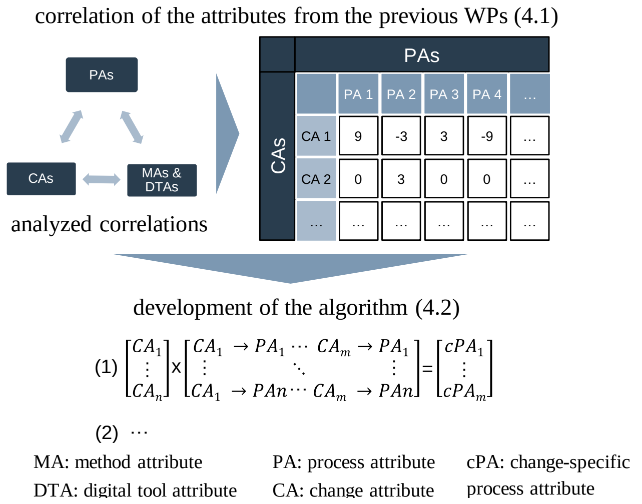

Figure 5: Correlation of the attributes and development of the algorithm

In step 4, an overall application methodology is also developed. This application methodology combines the application methods from the previous steps. Once the individual methods from step 1 to step 4 have been run through, the methodology can be used operationally. For this purpose, an upcoming change is evaluated using the selected change attributes from step 2. This evaluation is then used as input for the company-specific correlation model, which originates from step 4. This model then outputs a change-specific process with suitable assigned M&DT, which can be represented as a matrix or a process model such as Business Process Modelling Notation 2.0 (BPMN 2.0).

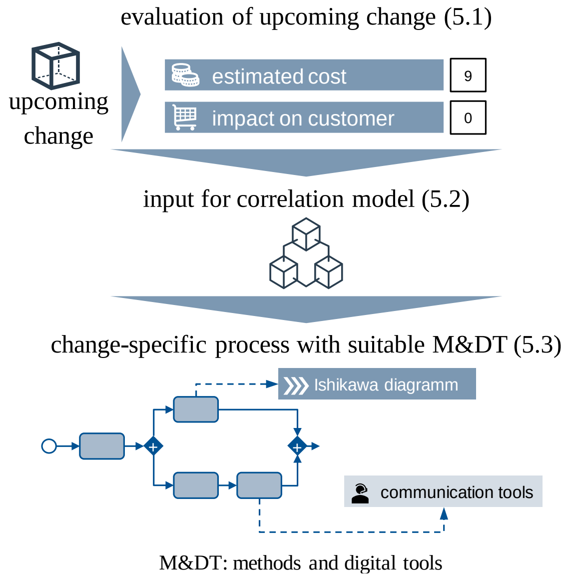

Figure 6: User application method

5. Discussion and outlook

As the outlined methodology is currently in its conceptual phase, there is a need for a more thorough elaboration in the future. The individual steps of the proposed approach are to be explained on a more detailed level in future publications. Furthermore, the methodology should be applied and validated through case studies in different manufacturing companies. This validation presents a significant challenge in quantifying the impact on improving the efficiency and effectiveness of MCs. Establishing measurable criteria and metrics to assess the methodology's success in real-world applications is a complex but critical task that requires careful consideration and collaboration with industry partners. In addition, the reliance on expert interviews to obtain essential insights and data adds another layer of challenges. The qualitative nature of expert knowledge requires a careful approach to ensure the reliability and validity of the information gathered [25]. Balancing the diversity of perspectives among experts and addressing potential biases for extracting and synthesizing relevant insights are critical issues [26] that require careful attention while applying the proposed approach. Furthermore, gaining access to an organization's MCM processes and data is a practical challenge. The sensitivity and confidentiality surrounding corporate information can hinder seamless collaboration and data sharing. Developing mechanisms to overcome these barriers and building trust with industry partners to facilitate data access and sharing is essential to successfully implementing and validating the methodology.

6. Summary

This contribution outlines an approach for the effective and efficient management of MCs, focusing on supporting company-individual MCM processes change-specifically regarding flexibility, digital support, and methodological support. The methodology comprises four steps: process description, change description, methods and digital tools, and correlation. The process description involves creating a description framework for MCM processes with process attributes and emerging process information. The change description involves systematically describing MCs through change attributes and iteration steps. The third package identifies and structures methods and digital tools, also using description attributes. The final step correlates process, change, and method/digital tool attributes through a Delphi study. The overall application methodology combines all the steps to be taken by a potential user and allows manufacturing companies to derive the necessary process steps and suitable methods and digital tools for a specific change based on their MCM process.

Acknowledgments

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 465491927. We would like to express our sincere thanks to the DFG for funding this research.

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