A METHOD TO SUPPORT THE IMPROVEMENT OF KNOWLEDGE TRANSFERS IN PRODUCT AND PRODUCTION ENGINEERING

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ABSTRACT

The product engineering process as part of the product life cycle includes product and production system development as well as production. In integrated product and production engineering (PPE), knowledge transfer is an important success factor. Optimizing the efficiency and effectiveness of knowledge transfers can, for example, support the avoidance of costly, production-related changes to the product design. The current state of research describes different models of knowledge transfer as well as factors that influence it. Some results show how the speed and quality of knowledge transfer can be improved by implementing so-called interventions. However, those models either represent abstract contexts of knowledge transfer or focus only on product engineering. Therefore, a literature analysis is conducted to identify the system of objectives for a method, that supports the improvement of knowledge transfer in PPE. Subsequently, the system of objectives is operationalized to provide the basis for the InKTI – Interdepartmental Knowledge Transfer Improvement Method, which is applicable, supports the user in improving knowledge transfers in PPE, and aims to increase the quality and speed of knowledge transfers.

Keywords: Knowledge management, Integrated product development, Optimisation, System of Objectives, Support Method

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Cite this article: Klippert, M., von Klitzing, M., Rapp, S., Albers, A. (2023) 'A Method to Support the Improvement of Knowledge Transfers in Product and Production Engineering', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.29

1 INTRODUCTION

The product engineering process as part of the product life cycle includes product as well as production system development, and to some extent, production (VDI 2221, 2019; Grote et al., 2014). For the successful development and production of a product, these must be considered in an integrated rather than an isolated manner, so knowledge transfer is an important success factor (Albers and Gausemeier, 2012). Especially in larger and distributed teams or knowledge-intensive environments managing intellectual property is a key requirement (McMahon et al., 2004). Improving the efficiency (speed) and effectiveness (quality) of knowledge transfers can, for example, support the avoidance of costly, production-related changes to the product design. In the current state of research, some results show how the speed and quality of knowledge transfer can be improved. By implementing so-called interventions, which affect defined influencing factors of knowledge transfer, positive effects could be proven in a product engineering context (Albers et al. 2019; Klippert et al., 2023c). However, those models either represent abstract contexts of knowledge transfer or focus only on product engineering. Therefore, this paper investigates how to develop a method that supports the improvement of knowledge transfers in product and production engineering. By conducting a literature analysis, the system of objectives (including objectives and requirements) (Albers et al., 2016) for this method is identified. Subsequently, the system of objectives is operationalized to provide the basis for a method that is applicable, supports the user in improving knowledge transfers in product and production engineering, and aims to increase the quality and speed of knowledge transfers. Increasing the quality and speed of knowledge transfers might lead to a reduction of cost-intensive changes or a decrease in development time. The InKTI – Interdepartmental Knowledge Transfer Improvement Method and its activities including the purpose, content, and potential outcomes are described. The method presented here is a result of two field studies, in which the method has been applied to ensure continuous validation (one study is presented in Klippert et al., 2023b).

2 STATE OF RESEARCH

2.1 Product and production engineering

Product development as part of the product life cycle (Vajna et al., 2009) consists of product planning, product development, production system development, and manufacturing (VDI 2221, 2019; Grote et al., 2014). This paper focuses on product and production system development as well as production, which in the following is referred to as product and production engineering (PPE). The concept of PPE describes a fundamental process of developing a product starting with a product or business idea and ending with the serial production or introduction (Albers and Gausemeier, 2012). This process involves nearly every department or business unit and via interdepartmental collaboration, each partial solution is combined as an overall approach (Ehrlenspiel and Meerkamm, 2017). Activities within product engineering are processed by interdisciplinary teams in a sequential or synchronized manner where communication and collaboration are keys (VDI 2221, 2019). Spath and Dangelmeier (2016) describe a current phenomenon, which disrupts the traditional perspective on the process, and the sequential order of activities is replaced by a holistic and synchronized or parallel process addressing the whole product life cycle. Besides any product development, the production system development is executed in parallel as well. This includes activities such as sequence and process planning, planning of working sites, equipment, and resources as well as logistics planning. Since product and production system development are often interdependent units, it is important to synchronize and align them well (Albers and Gausemeier, 2012). It can be concluded that PPE is a rather complex and interdisciplinary process that includes several units of a company and shifts towards increasingly parallelized, synchronized, and interdepartmental activities potentially leading to the intensification of knowledge transfers in PPE. The literature provides various approaches to how to design and shape PPE. Albers and Gausemeier (2012) introduce parameters that are clustered in *human*, *organisation*, *tools*, and the focus of this paper, *knowledge (including knowledge transfer)*. Product engineering and its activities can be described through process models (e.g., iPeM – integrated Product engineering Model), which aim to cut the time of development and increase product quality (Albers et al., 2016). The iPeM addresses stronger interdisciplinarity and overlapping. This model includes aspects of the system and model theory and consists of three main parts: the system of objectives (including objectives and requirements), the operation system, and the system of objects. All parts are iteratively connected by analysis and synthesis

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(Albers and Gausemeier, 2012). The iPeM also describes the relationship between the product and production system as well as the validation system and strategy. All layers are connected by the system of objectives and the system of resources (such as employees). In addition, systematic approaches to enable integrated product engineering are simultaneous engineering, which addresses the key factor of parallelizing activities and overlapping tasks or processes (VDI 2221, 2019; Putnik G. and Putnik Z., 2019) or Product-Production-CoDesign (PCCD) (Albers et al. 2022).

2.2 Knowledge transfer in product and production engineering

Knowledge can be characterized by the entirety of skills, understanding, and experience which is used by individuals to solve problems and divided into two types (North, 2016). Firstly, implicit or tacit knowledge is knowledge, which is not conscious or knowledge that is hard to articulate, therefore not formalized or documented, and the result of subjective and individual experience (e.g., routines). Secondly, explicit knowledge is mostly formalized, articulated, and documented knowledge that can be transferred between parties and stored afterward (e.g., work instructions or documented procedures). Also, individuals are conscious of it (North, 2016). Tacit knowledge can be transformed into explicit knowledge according to the SECI model (Nonaka and Takeuchi, 2016) and can act as a foundation for knowledge transfer regarding implicit knowledge. It becomes clear that particular focus must be placed on tacit knowledge in the context of recognition and transfer. According to Grum et al. (2021), knowledge transfer can be defined as the "identification of knowledge, its transmission from knowledge carrier to knowledge receiver, and its utilization by the knowledge receiver". Its activities consist of development, procurement, transfer, integration, and advancement or further development of knowledge (North, 2016). Because product engineering unifies several departments and subject areas (Ehrlenspiel and Meerkamm, 2017) and distributing knowledge requires certainty about what information needs to be delivered to which entity (Pawlowsky, 2017) knowledge management including knowledge transfer can be one of the most difficult aspects. The product engineering process is characterized as complex and requires a high level of knowledge (Binz, Roth, and Laukemann, 2016). Albers and Gausemeier (2012) characterize product engineering as "knowledge work" and argue that generating product ideas, inventions, and innovations requires individual knowledge which is often tacit. The knowledge work aims to explicate, store, and enable accessibility regarding knowledge to enable distributed collaboration and shall support identifying patterns, manage the knowledge overflow and provide knowledge. Cummings and Teng (2003) determine successful knowledge transfers by the aspects of the transfers being within the planned time frame and budget but also if they meet the requirements of the recipient, as in regards to the number of knowledge transfers, the "degree to which the knowledge is re-created" and the utilization and utility of transferred knowledge. Successful knowledge transfer results in improved quality, reduced response time, fewer errors, and lower costs or learning and innovation (Liyanage et al., 2009).

2.3 Improvement of knowledge transfer in product and production engineering

Liyanage et al. (2009) provide different theoretical aspects of knowledge transfers including awareness, acquisition, transformation, association, application, and knowledge externalization/ feedback. It describes the modes of knowledge transfer regarding the SECI model, the performance criteria, and the factors that influence the transfer process. From a theoretical point of view, it offers a broad foundation for an approach to model knowledge transfers but lacks practical applicability, specific design approaches and activities or tools, and sufficient relation to PPE. Teng (2011) proposes an approach for knowledge transfer mechanisms regarding various levels of tacit knowledge. These mechanisms as well as communication media are addressed to examine their relevance and effectiveness for transfers of different degrees of tacitness and enable to choose an appropriate design of transfer mechanisms and technology such as observation and best practices. All mechanisms are mapped to the suitable level of tacitness as well as different kinds of communication media. Even though the framework is very suitable for identifying specific techniques and tools to enable knowledge transfers of tacit knowledge, it not only lacks a holistic view regarding the process of knowledge transfer and a relation to PPE but also a designed method to tackle all parts of the transfer process including formalized methods for explicit and formal knowledge. Shen et al. (2015) provide an approach to how to address different types of knowledge regarding a transferring process. It states, that both structured, suitable for embedded, explicit knowledge (Davenport et al., 1998; Chen et al., 2010), and unstructured knowledge transfer processes, appropriate for non-formalized, tacit, or

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articulated knowledge (Chen et al., 2010) are required. Shen et al. (2015) describe an approach to facilitate knowledge transfer effectiveness (KTE), by assessing which impact different transfer processes have. In addition, they assess how certain characteristics of knowledge affect this interaction. They suggest multiple approaches and the design of transfer processes containing structured and unstructured knowledge transfer based on the different and specific knowledge contexts regarding embedded or articulated knowledge as well as in regards to different organizational knowledge. In this matter, they provide a basic concept of a fundamental strategy for how to select the appropriate knowledge transfer processes regarding the characteristics of knowledge and its context. This concept lacks to promote specific design approaches regarding the structure and activities of knowledge transfers as well as methods to identify knowledge transfers in the first place. Albers et al. (2018) assessed influencing factors and methods of knowledge transfer to enhance the speed of the transfer process. They provide a comprehensive list of influencing factors with an evaluation of their relevance as well as findings regarding specific knowledge transfer situations. Further Grum et al. (2019) address the speed of knowledge transfers. They propose to realize a more detailed and holistic description of knowledge transfer situations by characterizing them regarding each influencing factor's value and utilizing interventions to enhance the speed of the transfer. All aspects focus on PGE – Product Generation Engineering (Albers et al., 2019) and are not fully fitting in the context of PPE, but act as a first orientation for the intended method (Sec. 5), regarding the assessment of knowledge transfer situations and influencing factors to improve the transfer process. Also, Albers et al. (2019) presented the Knowledge Transfer Velocity Model (KTVM) to improve the speed of knowledge transfers. Grum et al. (2021a) are assessing the quality of knowledge transfer regarding the correctness, relevance, clarity, systematic structure, and comparability. They introduce a morphological box to support the identification of reference situations and to describe knowledge transfer situations regarding eight dimensions and their characteristics. They conceptualize knowledge transfers and their influencing factors, providing a foundation for examining them and an initial six-step procedure to identify and utilize improvement potentials. Grum et al. (2021) initially contribute an approach to systematically identify and describe knowledge transfer situations, but also a concept to assess the influencing factors and quality. Based on the KTVM and the findings of Grum et al. (2021), Klippert et al. (2023d) introduce the Knowledge Transfer Quality Model (KTQM) to improve the quality of knowledge transfers. Both KTVM and KTQM focus on a product engineering context only. Grum et al. (2021b) introduce an approach for knowledge transfer improvement in intelligent cyber-physical systems based on Gronau and Grum (2019) and provide a proceeding with 7 steps. This framework for knowledge transfer improvement incorporates factors for operationalization. Although this approach is promising, it is specific to knowledge transfer in cyber-physical systems and does not fit the context of PPE. Following Gronau and Grum (2019), as they provide an overview of the literature regarding research approaches to knowledge transfer, the authors of this paper also compare the literature from this section to underline their objective of research and fulfillment of aspects that are relevant for a method to improve knowledge transfer in PPE (Fig. 1).

		Aspects							
Object of Research	**Reference**	**Theoretical Approach**	**Modelling**	**Design Approach**	**Tools and Activities**	**Success Criteria**	**Velocity**	**Quality**	**PPE**
Assessment of influencing factors and methods of knowledge transfer to enhance transfer speed	Albers et al. (2018)	◐	○	◐	◐	◐	●	○	◐
Optimizing the speed of knowledge transfers	Grum et al. (2019)	◐	○	○	◐	◐	●	○	◐
Quality of knowledge transfers and conzeptualization of transfers and their influencing factors in Experimentation	Grum et al. (2021)	◐	◐	◐	◐	◐	○	●	○
Knowledge transfer optimization in intelligent cyber-physical systems	Grum et al. (2022)	◐	◐	◐	◐	◐	◐	◐	○
Optimizing the quality of knowledge transfers	Klippert et al. (2022a)	◐	○	○	◐	◐	○	◐	◐
Theoretical models and modes of knowledge transfer	Liyanage et al. (2009)	●	◐	○	○	○	○	○	○
Type of knowledge transfer regarding type of knowledge	Shen et al. (2015)	◐	◐	◐	◐	○	○	○	○
Knowledge transfer mechanism regarding the tacitness of knowledge	Teng (2011)	◐	◐	◐	◐	○	○	○	○
not fulfilled = ○ partially fulfilled = ◐ completely fulfilled = ●									

Figure 1. Comparison of different research approaches for knowledge transfer

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The results show that no appropriate method is given regarding a holistic view, applicable activities, and concepts as well as a relation to PPE. Also, every reference is partly or fully theoretical in its approach.

3 AIM OF RESEARCH AND METHODOLOGY

In the current state of research, none of the approaches and models have a specific focus on knowledge transfer in PPE. To close the research gap and address the research need, this research aims to support the improvement of knowledge transfers in PPE to increase the speed and quality of knowledge transfers. Thus, the following research questions (RQ) will be answered:

RQ1. What is the system of objectives for a method to support the improvement of knowledge transfers in product and production engineering?

RQ2. How can the system of objectives be operationalized in the method development?

To answer RQ1 a literature analysis is conducted as a method of qualitative research to define the system of objectives (including objectives and requirements) of this method. Since the method needs to be validated, the identified objectives and requirements are assigned to the evaluation criteria based on the Design Research Methodology (DRM) by Blessing and Chakrabarti (2009). These are the contribution to success, support performance, and applicability (Sec. 4). To answer the RQ2 the objectives and requirements are operationalized to provide the basis for a method that is applicable, supports the user in improving knowledge transfers in PPE, and aims to increase the quality and speed of knowledge transfers. As a result, the InKTI Method and its activities including the purpose, content, and potential outcomes are described (Sec. 5).

4 SYSTEM OF OBJECTIVES OF A METHOD TO SUPPORT THE IMPROVEMENT OF KNOWLEDGE TRANSFERS IN PRODUCT AND PRODUCTION ENGINEERING

To describe the system of objectives for a method, that supports the improvement of knowledge transfer in PPE a literature analysis is conducted to identify objectives and requirements as the initial research only revealed the first relevant parameters such as speed and quality of knowledge transfers without underlining them as objectives or requirements. Based on this literature search and analysis including several databases (e.g., Google Scholar, Research Gate), a further 7 publications were selected (Fig. 2 to 4) to provide 58 objectives and requirements in total. Within several workshops of a research group (five people), similar requirements were clustered into 9 topic areas to avoid redundancies or duplications and to bundle similar aspects under a few keywords. These clusters thus served as a basis for the synthesis of requirements and due to the higher degree of generality and a low level of granularity, the clusters allow for more unrestricted identification of objectives and requirements suitable without operating too far outside the literature-determined boundaries. Based on that 16 objectives and requirements for the method under investigation were derived and assigned to one of the criteria regarding *success evaluation, support evaluation,* or *application evaluation*.

Success Evaluation: The two identified objectives and requirements of the method for the success evaluation according to the DRM are shown in Figure 2. The objectives and requirements to support the improvement of knowledge transfers in PPE are the increase of the quality (E1) and the speed (E2) of knowledge transfers (Sec. 2.3).

Objectives and requirements for the success evaluation of the method		
	The method should…	**Reference**
E1	…increase the quality of knowledge transfers.	Geis et al. (2008), Grabowski and Geiger (1997)
E2	…increase the speed of knowledge transfers.	Dühr et al. (2022)

Figure 2. Objectives and requirements for the success evaluation of the method

Support Evaluation: Figure 3 shows the objectives and requirements of the method for the support evaluation according to the DRM. To improve knowledge transfers in PPE it is a prerequisite to support the identification (U1), explication (U2), and evaluation (U3) of knowledge transfer situations. Based on this the definition (U4) and implementation of defined (U5) interventions as well as their evaluation (U6) should be supported. The last objective and requirement for the support evaluation of the method is continuous documentation (U7).

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Objectives and requirements for the support evaluation of the method		
	The method should…	**Reference**
U1	…support the identification of knowledge transfer situations in product and production engineering.	Geis et al. (2008), Grabowski and Geiger (1997)
U2	…support the explication of knowledge transfer situations in product and production engineering.	Beckmann (2021)
U3	…support the evaluation of knowledge transfer situations in product and production engineering.	Dühr et al. (2022)
U4	…support the definition of interventions to address knowledge transfer situations in product and production engineering.	Geis et al. (2008), Grabowski and Geiger (1997)
U5	… support the implementation of defined interventions to address knowledge transfer situations in product and production engineering.	Dühr et al. (2022), Beckmann (2021)
U6	…support the evaluation of implemented interventions to address knowledge transfer situations in product and production engineering.	Dühr et al. (2022)
U7	…provide documentation of knowledge transfer situations and interventions to address it.	Dühr et al. (2022)

Figure 3. Objectives and requirements for the support evaluation of the method

Application Evaluation: Seven objectives and requirements were identified for the application evaluation after the DRM, which are shown in Figure 4. For the applicability of knowledge transfers, the method should have a reasonable ratio of effort and benefit (A1). Furthermore, it should be easy to apply (A2), be divided into meaningful steps (A3), and have an appropriate level of detail (A4). The method should also be able to be integrated into existing processes (A5), be adaptable to the situation and needs (A6) as well as provide sufficient opportunities for its further development (A7).

Objectives and requirements for the application evaluation of the method		
	The method should…	**Reference**
A1	…have a reasonable ratio of effort and benefit.	Reinicke (2004), Jänsch (2007), Beckmann (2021)
A2	…be easy to apply.	Reinicke (2004), Jänsch (2007), Dühr et al. (2022)
A3	…be divided into meaningful steps.	Jänsch (2007), Beckmann (2021)
A4	…have an appropriate level of detail.	Dühr et al. (2022)
A5	…be able to be integrated into existing processes.	Jänsch (2007), Geis et al. (2008)
A6	…be adaptable to the situation and needs.	Badke-Schaub et al. (2005), Geis et al. (2008), Jänsch (2007), Beckmann (2021)
A7	…provide sufficient opportunities for its further development.	Jänsch (2007), Beckmann (2021), Dühr et al. (2022)

Figure 4. Objectives and requirements for the application evaluation of the method

To develop the intended method, the identified objectives and requirements are operationalized (Sec. 5.). The evaluation of those objectives and requirements after the application of the method is presented in Klippert et al. (2023b).

5 INKTI – INTERDEPARTMENTAL KNOWLEDGE TRANSFER IMPROVEMENT METHOD

To address the existing research gap regarding the improvement of knowledge transfers in PPE and to operationalize the system of objectives (Sec. 4), the InKTI Method is provided. The InKTI Method is iteratively developed in workshops and implemented in two consecutive field studies to continuously validate the method by applying it to different industrial environments (one study is presented in Klippert et al., 2023b). The method presented here is the result of several iterations. This method is primarily designed for application in a developing and producing company and can be applied at any stage in the engineering process, but not across organizational boundaries (cf. Klippert et al., 2023b). It aims to improve knowledge transfers in PPE by, first, supporting the identification and explication of situations, in which knowledge is transferred. Any identified knowledge transfer can be explicated by describing various general but also situational aspects. This enables the user to evaluate those knowledge transfer situations and to identify any gaps or potentials. Additionally, it supports identifying and prioritizing improvement needs. And second, this evaluation is the foundation to define, implement and evaluate

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interventions, which address the improvement needs. The knowledge addressed by the method is the subject of the transfer and differs depending on the context of the knowledge transfer situation. The InKTI Method consists of the following five activities: *identify knowledge transfer situations* (activity 1, U1), *explicate and evaluate knowledge transfer situations* (activity 2, U2, and U3), *define* (activity 3, U4), *implement* (activity 4, U5) and *evaluate* (activity 5, U6) *knowledge transfer interventions* (see Fig. 5). Each activity follows a distinct purpose, contains specific parts and tasks and provides a certain outcome. All activities are framed by continuous documentation (U7), which not only ensures the opportunity to always get back to earlier results but also allows the user to evaluate the method and maximize the lessons learned. In the following, each of the activities of the InKTI Method is described in detail. To illustrate and clarify the different activities, an example is given. It should be noted that this example is simplified and in a real environment, both the process and results of the method can be very extensive and significantly relevant.

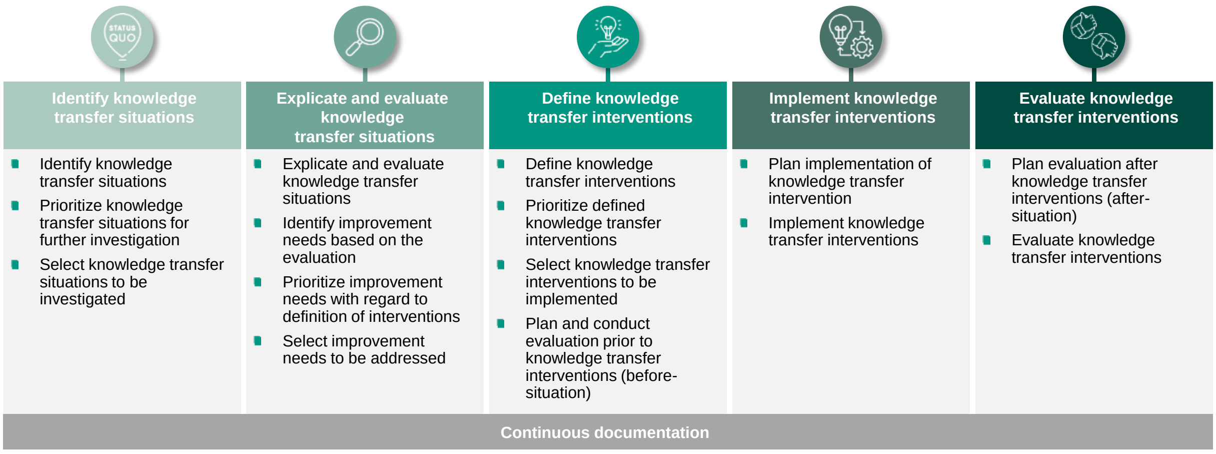

Figure 5: InKTI – Interdepartmental Knowledge Transfer Improvement Method to support the improvement of knowledge transfers in product and production engineering

Identify knowledge transfer situations (activity 1): The first activity's purpose aims to identify actual situations of knowledge transfer, to describe the knowledge transfer by the identified situation, to explicate the knowledge transfer regarding various aspects, and prioritize them for further investigation. To do so, a comparison through an exemplary catalog of knowledge transfer situations, which is provided by Klippert et al. (2023a) can be utilized. This catalog was developed through literature analysis and field studies and contains knowledge transfer situations such as weekly meetings, milestones for decision-making, or idea workshops. In the next step prioritizing the identified knowledge transfer situations by the user of the method allows focusing on the most relevant ones for the step of explication. In this example, the most relevant one is a *regular meeting for the coordination of new product components*. At this point, it is necessary to mention, that every other knowledge transfer situation is stored within the continuous documentation. The outcomes of the first activity are identified and prioritized knowledge transfer situations in PPE.

Explicate and evaluate knowledge transfer situations (activity 2): The second activity aims at explicating and evaluating the identified knowledge transfers. To explicate the knowledge transfer it is essential to describe and formalize its contextual and situational aspects. Therefore, Klippert et al. (2023a) describe knowledge transfers by 65 characteristics and provide guiding questions for each of those characteristics to investigate their values. Regarding the application of the method, users should attempt to consider every characteristic, to fully explicate the knowledge transfer. The characteristics are divided into 10 categories: *(1) organizational structure, (2) goals and knowledge culture, (3) knowledge management, (4) interdepartmental collaboration, (5) context of the transfer situation, (6) communication, (7) technology and tools, (8) interpersonal, (9) characteristics of knowledge, (10) personal competences*. With the support of the guiding questions, each characteristic's attribute has to be picked from a fixed, predetermined range of mostly qualitative attributes, which are defined as between a favorable to an unfavorable condition. In this specific example, two (of 65) characteristics will be investigated representatively: (a) *goals of transfer* and (b) *interrelation of business units* which are both assigned to a category (1). Those characteristics (a) and (b) can be explicated by the guiding questions of Klippert et al. (2023a), such as *"what is the purpose of knowledge sharing in terms of transmission,*

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storage, processing, and application of that knowledge?" or *"do teams exist across different units and departments or are teams separated by intersections?"*. This step supports setting a suitable attribute as well. Hence, for characteristic (a) an attribute is set that is either *solving a problem, informing those affected,* or *has no goals.* Following this example, the knowledge transfer goals are informing those affected, which might be a result of a discussion with several members of different units. For characteristic (b) an attribute is set, that is either *interrelated, partially interrelated,* or *not interrelated.* A survey of affected units could show, that all of them are partially interrelated. The outcomes of the first step are explicated knowledge transfer situations in PPE with their characteristics and values. Based on the attributes, which were introduced as the values of the characteristics in the first step, the next step is to evaluate, whether there is an improvement need to alter certain characteristics towards a more favorable attribute (e.g., mutual goals) or not (e.g., no goals/ not formulated goals). Subsequently, the identified improvement needs are prioritized by the user to support the definition of interventions in the next activity. To execute this task, an evaluation regarding the criteria magnitude, and relevance of any improvement need is recommended. Both criteria can be set on a scale of qualitative or quantitative measures. To determine an appropriate evaluation of any characteristic, the user for example can conduct a survey containing a template and use a quantitative approach to measure results or engage key roles in a discussion about the knowledge transfer situations to get an evaluation through them. Getting back to the example, a team discussion and an additional survey could reveal that the attribute *informing those affected* by the characteristic (a) indicates a *strong improvement need* with *high relevance,* and the attribute *partially interrelated* with characteristic (b) indicates a *minor improvement need* but with also *high relevance*. The outcomes of this activity are evaluated characteristics of knowledge transfer as well as identified, prioritized, and selected improvement needs.

Define knowledge transfer interventions (activity 3): The third activity's purpose is to define and select interventions to improve the knowledge transfer by addressing the improvement needs which were derived in activity two. After the second activity, the selected improvement needs can now be assessed in workshops, meetings or surveys, and other forms of interaction to analyze and cluster them. This helps to define areas of interest where potential interventions can have a positive impact and improve knowledge transfer. Further workshops, discussions, or surveys can be utilized to deduce and define knowledge transfer interventions based on the improvement needs and the areas of interest respectively. Also, interventions are prioritized regarding their potential effect or relevance. The next step of this activity aims at selecting suitable interventions and setting them up for implementation in the following step. To do so, the previously defined prioritization is considered and related to the situation at hand. Also, the potential impact of any intervention is estimated or examined to assess their contribution to the objective. In this example, various interventions could be defined. The most promising one and also most prioritized to address both characteristics (a) and (b) could be a *round table meeting to define mutual goals and interdepartmental, interdisciplinary teams*. When selecting interventions, the evaluation of the current knowledge situation needs to be planned and conducted. The outcomes of this activity are selected interventions and the evaluation of the before-situation, which will be implemented in the next activity of the method.

Implement knowledge transfer interventions (activity 4): After defining and selecting suitable interventions, the fourth activity's purpose is to implement and execute them. The first step is to plan e.g., which tasks, resources, tools, departments, teams, persons, and roles involved, are required to execute the implementation. Structured planning and scheduling can support the success of the undertaking (Dvir et al., 2003). The second step consists of implementing the intervention and executing them. To implement the exemplary intervention, a round table meeting to define mutual goals and interdepartmental, interdisciplinary teams, a *plan for a schedule, topic, and participants followed by an invitation of persons involved and execution of the meeting* could be set up. The outcome of this activity is an implementation plan, which is executed and will be evaluated next.

Evaluate knowledge transfer interventions (activity 5): The fifth and last activity aims to evaluate the knowledge transfer interventions, e.g., in a quantitative or qualitative and subjective or objective manner. If gaps or inadequacies are identified during the evaluation, activity four can be repeated to replace any implemented interventions with new ones from the continuous documentation. After that, the knowledge transfer situation should be evaluated again. The results of the before-situation can then be compared with the after-situation. This last activity offers a chance to derive lessons learned or even new knowledge from the whole process and its procedures as well. In this example, the intervention could be evaluated as successful. Further lessons learned as *regular, recurring round* *table meetings as fixed principles to enable and improve collaborative work* could be derived. The outcomes of the last activity are evaluated interventions and further improvement potentials.

6 CONCLUSION AND OUTLOOK

Product and production system development as well as production are an essential part of the product life cycle. To increase the efficiency and effectiveness in PPE, various approaches are proposed in the literature, e.g. integrated product development, simultaneous engineering, and Product-Production-CoDesign. They all emphasize, that knowledge management (here in particular knowledge transfer) is a decisive factor for success. Knowledge transfer in general is described by many different authors, but only a few focus on improving knowledge transfers. None of those approaches, models, and methods investigate how to improve knowledge transfers in PPE. Therefore, this paper aimed to develop a method, which addresses this research gap. To answer RQ1 various approaches in the literature, that address the objectives and requirements of methods, in general, have been analyzed. In total, 2 objectives and requirements were identified for the success evaluation, 7 for the support evaluation, and 7 for the application evaluation of a method, which aims to support the improvement of knowledge transfers in PPE. These objectives and requirements were operationalized in the InKTI Method to answer RQ2. This method includes the five main activities *identify knowledge transfer situations* (activity 1), *explicate and evaluate knowledge transfer situations* (activity 2), *define* (activity 3), *implement* (activity 4), and *evaluate* (activity 5) *knowledge transfer interventions*. To illustrate and clarify the different activities, an example is given throughout (Sec. 5). In future research, the activities of the InKTI Method are yet to be unpinned by further approaches from the literature. Since the InKTI Method is already validated in two field studies (one of which is presented in Klippert et al., 2023b), the method could be validated in another industrial environment or other validation environments (e.g., laboratory study or Live-Lab study). This way the identified objectives and requirements of the method and the method's activities itself can be validated through a practical application. The goal of the validation is to prove whether the application of the method can increase the speed and quality of knowledge transfers in PPE. Lastly, further improvements to the method could be identified.

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