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Shared digital artifacts – Co-creators as beneficiaries in microlearning development

Marian Thiel de Gafenco[1] · Tim Weinert[2] · Andreas Janson[3] · Jens Klusmeyer[1] · Jan Marco Leimeister[2,3]

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Abstract
Continuing vocational training benefits from the employees' ability to share individual experience and expertise with their co-workers, as these assets constitute competitive advantages for companies. IT-supported systems can facilitate processes of knowledge elicitation (e. g. as part of collaborative co-creation) to ensure retainment of preferred qualitative characteristics of the resulting knowledge artifacts and provide ample opportunities to manage and configure a growing number of such artifacts in a company's repository. It remains unclear however, how such collaborative and digital co-creation processes can benefit the individual co-creators' expertise development. To address this gap in research and practice, an IT-supported co-creation system for microlearnings is designed and evaluated with master craftsman trainees of an inter-company vocational training center. With the deployment of the co-creation system, knowledge elaboration was examined via a qualitative evaluation of concept maps. By applying categories of the maps' semantic properties and comparing features of expert knowledge derived from expertise research and concept mapping literature, we evaluate the process' function to support expert knowledge elaboration as a desirable learning outcome for co-creators of shared digital artifacts. Analysis of the concept maps shows an absence of theoretical reasoning and an emphasis on contextual factors with minute details of work processes, indicating more practical than expert knowledge formation when co-creating shared digital artifacts. To improve the IT system's effective support for expert knowledge elicitation, adjustments to the structured procedure are discussed and future research directions and limitations of this study are addressed.

Keywords Co-Creation · Microlearnings · Concept Maps · Knowledge Elicitation · Vocational Education and Training · Digital Artifacts

✉ Marian Thiel de Gafenco
thiel.de.gafenco@uni-kassel.de

Extended author information available on the last page of the article

1 Introduction

In vocational education and training (VET), an increasing number of instructional IT-systems promise to leverage the potential of a thorough work process integration (Baceviciute et al., 2021; Howe, 2008) and collaboration in the informal self-directed learning of employees (Coll et al., 2014; Zhang et al., 2016). With the accelerated digitization and automation of work, these instructional IT-systems are widely used in on-the-job training that addresses the decreasing half-life of skills acquired in formal educational settings (Senderek, 2016), thus making an important contribution to lifelong learning (Teo et al., 2021). In this context, the inadequacy of learning resources to address specific training needs in enterprises serves as an obstacle for work-process-integrated training (Schmidt, 2007). Approaches of so-called co-creation (Bovill, 2020) have gained popularity, which aim at harnessing expert knowledge of concrete work processes and sharing it among employees. By using IT-Systems that support the elicitation and extension of expert knowledge, these collaborative methods can guide the generation of truly new knowledge or support the formation of shared digital knowledge artifacts, such as microlearnings (MLEs) (Bovill, 2020; Schaefer et al., 2019), with a convergence of a company's vocational training and knowledge management efforts as a by-product (Bittner & Leimeister, 2014).

However, in order to establish a continuing vocational training with MLEs, these IT-systems must be adapted and integrated into work processes, thus gaining access to the necessary contexts and sources of diverse media content of such knowledge artifacts (Jalonen et al., 2011; Langreiter & Bolka, 2006). Since MLEs have been established to cope with the aforementioned changes in the reality of work, the co-creation of MLE at the workplace opens up new possibilities for work-process-integrated training (Horst & Dörner, 2019; Langreiter & Bolka, 2006). Therefore, we anticipate that IT-supported co-creation systems, as a procedural framework for MLE generation, can support the role of MLE in professional development in continuing vocational training by facilitating knowledge elicitation efforts and considering social and contextual aspects of learning (Bovill et al., 2016; Gerbaudo et al., 2021).

While both institutional and potential learner benefits of MLE co-creation have been well researched (Langreiter & Bolka, 2006; Ley, 2020; Puah et al., 2021), little is known about the implications for co-creators beyond increased motivation and self-efficacy in the case of co-creating shared digital MLE artifacts (Bovill, 2020; Nikou & Economides, 2018). Therefore, this paper aims to explore possible advances in expert knowledge formation by focusing on the elaborative nature of IT-supported co-creation and the knowledge elicitation involved. In this context, we highlight the distinctive nature of IT-supported co-creation that warrants a fresh look at MLE on a conceptual level against the background of co-creation and knowledge elaboration, e.g., by harnessing the pedagogical benefits of self-authorship (Baxter Magolda, 2007) and social meta-learning practices (Cook-Sather et al., 2014). We have initiated the development of an IT-supported co-creation system, which has been adapted to the conditions of manufacturing to facilitate both learning with MLE as well as co-creating MLE in the process of work. In doing so, we aim to demonstrate whether the elicitation of expert knowledge in IT-supported co-creation of MLE promotes individual elaboration of expert knowledge as a desirable learning outcome for co-creators. Thus, this study aims to answer the following research question (RQ):

RQ: *To what extent does the implementation of an IT-supported MLE co-creation system enhance knowledge elaboration among co-creators?*

To evaluate the effects of the IT-supported co-creation system on knowledge elaboration, we employed concept maps (CM) as an assessment and evaluation tool to visualize knowledge structures before and after MLE co-creation (Chang et al., 2022; Chang & Yang, 2022). From the central research question, we derived a qualitative hypothesis in line with the current state of research on expertise and expert knowledge as well as co-creation.

H1: IT-supported co-creation positively influences the elaboration of expert knowledge of co-creators on a semantic and structural level, exemplified by their knowledge elicitation in a concept mapping task.

We assume that IT-supported co-creation will have a positive impact on both the meaning-making process (semantic level) and several structural characteristics of knowledge representations. To substantiate this assumption we briefly present the theoretical background of our study in the next section. We then explain our methodology for data collection and analysis in an inter-company vocational training center. Finally, we discuss the role of co-creation in knowledge elaboration and derive implications for IT-supported knowledge elicitation with MLE co-creation. In addition, we contribute to CM research by providing insights into the application of the method in VET research (Chang et al., 2022). The development of the IT-system was embedded in a larger research project (Thiel de Gafenco et al., 2018; Weinert et al., 2023).

2 Related work

2.1 Knowledge elaboration in VET

The explication of tacit knowledge is still a major challenge for companies' knowledge management and learning initiatives (He & Wei, 2009). Various approaches, typically IT-supported, try to overcome this challenge. For example, Nakano et al. (2013) point out that an engaging environment can support knowledge elicitation. Pentland and Feldman (2008) show that certain routines in IT-systems can support the elicitation of tacit knowledge, especially work process knowledge. Work process knowledge is understood as the knowledge that is directly needed in the work process (Rauner & Maclean, 2008) and includes, at least in part, concrete work experience. To understand the importance of work process knowledge for work-process-integrated learning, the theory of situated cognition can be used. The theory, first posed by Dewey (1938), remains highly relevant for both the design of various forms of IT-supported learning (e.g., mobile learning) and to VET research. Here, knowledge is inseparable from action and situated in activities in diverse social, cultural, and physical contexts (Mensah et al., 2020). These activities can be of physical or representational nature, with the latter enabled by interactive systems (Levi, 2020). Collaborative knowledge elicitation and expansion, as well as support mechanisms such as coaching and scaffolding (Herrington & Oliver, 2000), are essential to leverage situated cognition for situated learning. Pérez-Sanagustín et al. (2015), as well as Hämäläinen et al. (2008), show that authentic situated learning environments with embedded interaction elements are beneficial for knowledge elaboration. Furthermore, shared contextual cues, such as the real work environment, can enhance shared knowledge elaboration (Ding, 2009).

Knowledge elaboration, as often associated with collaborative learning, occurs when individuals connect pieces of information in their minds (Ritchie & Karge, 1996), including restructuring and interconnecting of new information with prior knowledge (Reigeluth et al., 1980). By encouraging learner interaction, knowledge processing and modification of knowledge structures can be further promoted (Baker, 2003; Suthers et al., 2010), and both knowledge elaboration and extension can be stimulated through collaborative learning (Zheng et al., 2015). For IT-supported collaborative learning environments, elaborative explanations shared among learners are considered essential for knowledge expansion (Ding, 2009; Hämäläinen et al., 2008) and collaborative success. The negotiation of meaning during both collaborative learning (Lee et al., 2017) and collective design processes (Durall Gazulla et al., 2023) can thus be seen as one of the reasons for the co-construction of genuinely new (design) knowledge (Tseng et al., 2008; van Boxtel et al., 2000) and the building of expertise.

2.2 Expertise and expert knowledge

The term *expertise* is used by scholars, particularly in psychology, to refer to the manifestation of skills and understandings that lead to superior and reproducible performance in domain-specific tasks (Chi, 2006b; Posner, 1988). With the rise of IT-supported learning and knowledge management, the integration of different sources of smaller units of elicited knowledge into a broader representation of expert or work-process-knowledge remains a challenge (Sabitha et al., 2015). Furthermore, despite many uncertainties about the interconnectedness of practical and theoretical knowledge (Röben, 2008), both deliberate practice and learning are essential for expertise development (Chi, 2006b). Practice is not to be confused with formal process specifications (e.g., standard operating procedures) of what kind of work is to be done (Clancey, 2006). Instead, the distinction lies in the expectations of practitioners and their context-dependent (e.g., timing and location constraints) dynamic engagement with activities as individual expressions or summaries of work processes (Clancey, 2002). These practical characteristics of expertise also become important against the theoretical background of situated cognition and their respective IT-supported learning environments (Pérez-Sanagustín et al., 2015). Contextual cues or information, which include the use of technology in the work-process (McLellan, 1993), are prerequisites for experts to demonstrate their high level of performance (Chi, 2006b).

In addition to practice, the development of an extensive knowledge base is necessary for expert performance, and thedistinction between novices and experts can be implemented as an examination of their individual knowledge representations. These models differ in their (a) knowledge extent, measured by counting the number of factual statements, procedures, or similar units; (b) knowledge organization, often hierarchical, with missing levels or preferences regarding levels on which an individual operates; (c) depth of knowledge, with abstraction and concreteness or function and structure as variables to describe expertise; and (d) consolidation and integration, which allow for faster retrieval and processing of the represented knowledge (Chi, 2006a). Concept mapping is one of the most prominent methods to investigate these mental models or representations (Hoffman, 2002), which in turn can be used to build knowledge bases and interfaces for corporate knowledge management systems (Hoffman & Lintern, 2006), and can serve as learning support in professional training (C.-C. Chang & Hwang, 2022).

2.3 Co-creation of microlearnings

The dynamic nature of MLE typically involves the continuous creation, revision, and application of small units of information (Jahnke et al., 2020; Job et al., 2012). This type of learning resource is an innovative format to share digital knowledge artifacts easily (Hersh, 2017). By providing situationally embedded microcontent that addresses specific topics and is optimized for rapid consumption (Horst & Dörner, 2019), MLEs have adequate instructional properties to address the aforementioned challenges of work-process-integrated learning and expert knowledge dissemination. Their brevity implies not only effortless consumption but also production directly at the workplace, with both aspects being reinforced by an increasing availability of smart devices such as phones and tablet computers as access points and support channels for employees (Winkler et al., 2021). MLEs can be used in a targeted manner "on demand" by providing relevant standard procedures or problem solutions to satisfy information and learning needs that arise in the short term (Gerbaudo et al., 2021), as well as promoting the use of expert knowledge among employees when it emerges from knowledge elicitation (Ley, 2020; Tseng et al., 2008). However, to consider the necessary situational references of MLEs and the collaborative creation of artifacts, both processes and associated systems are needed to support employees in the systematic design of learning content.

In research, as well as in practice, an increasing number of ventures are trying to enable an employee-driven approach to the design of learning content by applying the concept of IT-supported co-creation. One reason for this is the positive influence on learners' engagement during co-creation and the resulting positive effects on their motivation (Eisenkopf, 2010). Co-creation, peer creation, or peers as teammates are terms that are often used interchangeably (Bovill, 2020). Generally, all these approaches are based on theories of social constructivism and refer to learning with and from colleagues, classmates, or fellow students, indicating the importance of mutual learning among those who participate in co-creation (Durall Gazulla et al., 2023). For vocational training, these concepts include processes that enable employees to design meaningful artifacts, such as digital learning materials, as they work. Employees add value to these digital artifacts by contributing their knowledge and collaboratively developing the artifact in digital collaborative learning environments (Tan et al., 2021).

In addition to the benefits of applying digital MLEs to corporate training, studies in other contexts (e.g., higher education) have shown that the process of co-creating digital learning resources can be beneficial to the co-creators (Bovill, 2020) by increasing autonomy, self-regulation, and responsibility (Deeley & Bovill, 2017), improving performance in higher education (Coetzee et al., 2015), or increasing critical reflection and communication skills (Deeley & Bovill, 2017). There are significant differences in the application of co-creation concepts, which can either focus on different contexts, actors, and goals, such as stimulating knowledge sharing in collaborative and elaborative processes in organizations (Bittner et al., 2021), or increasing student engagement in higher education courses (Howson & Weller, 2016).

Adapting a co-creation process to its application domain and the participants' contexts is critical for success (Bovill, 2020). In manufacturing, where documentation requirements are high, this includes the integration into daily work, enabled by the meaningful use of smart devices such as tablet computers and accompanying learning platforms. Our goal is to iteratively develop and progressively adapt a system for manufacturing as a general training environment by providing sufficient supporting design choices and features for MLE co-creation.

3 Method

3.1 Study overview

To answer our research question, we used a web-based co-creation system designed to support employees in developing and applying MLE for work-process-integrated learning. The development and adaptation of the IT-system was informed by the concept of co-creation as well as considerations of work-process-integrated learning in manufacturing and is embedded in a larger international action design research project (Billert et al., 2022; Thiel de Gafenco et al., 2018; Weinert et al., 2023). The system's deployment and evaluation procedure for the intervention study is shown in Fig. 1.

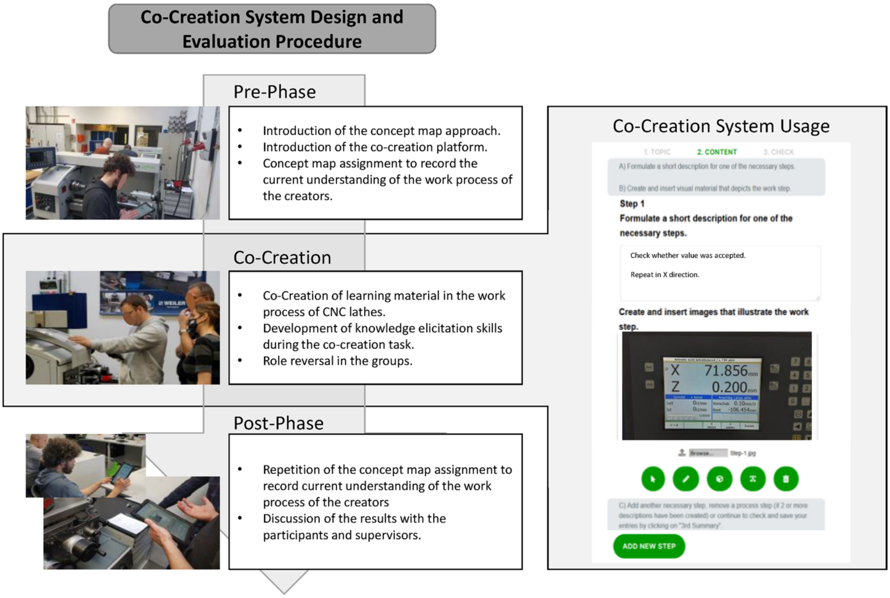


Fig. 1 Co-creation intervention and evaluation procedure

3.2 IT-supported co-creation intervention

Co-creation scenarios without IT-support may rely on more knowledgeable peers, such as supervisors, to support knowledge elicitation and elaboration (Janson et al., 2020; Wood et al., 1976). Daily work routines often preclude extensive collaborative efforts, making IT-support-systems more attractive for facilitating co-creation. Therefore, we initiated the development of an IT-based co-creation system suitable for work-process integration. The developmental practices approach (Dohn et al., 2020) provides a framework for an object-oriented activity design for such IT systems. Objects in this case refer to the shared digital artifacts, the MLEs, and the collaborative efforts of knowledge creation. Since our system aims to facilitate the acquisition of expert knowledge by employees, we follow the design principles of the developmental practices approach (Moen et al., 2012) and complement them with our own requirements for a learning system in manufacturing (Weinert et al., 2023). Furthermore, the system aims to provide means for collaborative knowledge work by making the processes of creating and improving digital artifacts visible and facilitating their distribution. Co-creators simultaneously take responsibility for their own work and for collaborative efforts in which individual expertise merges with the co-creation of knowledge. The co-creation process, i.e. the platform as well as the practices learned during the creation process, supports the creative reuse of previous activities and MLE, thus providing the basis for knowledge transfer and transformation. Since work processes are usually intertwined, the IT-supported development of MLE emphasizes the interaction between practices, conceptualizations, as well as different types of knowledge. VET entails different learning contexts (e.g.,

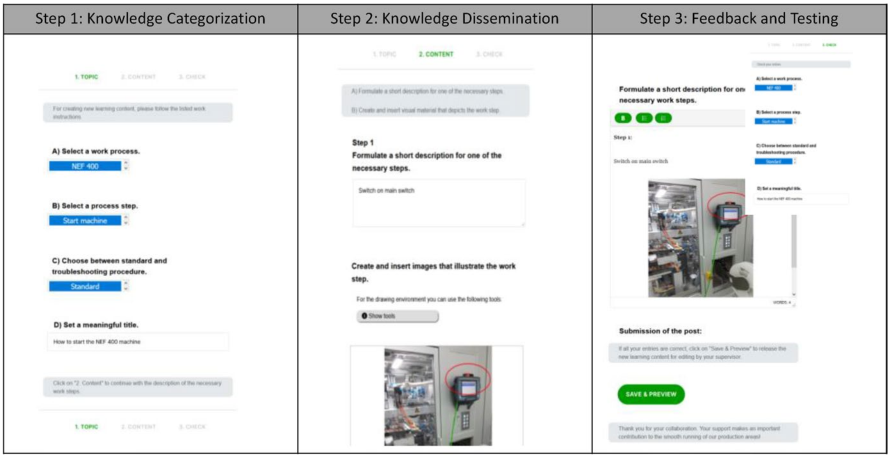


Fig. 2 Co-Creation System to support the knowledge elicitation of the employees

formalized in vocational schools and informal workplace learning), which means that both the MLEs and the co-creation process are relevant outside of strictly educational settings and institutions, thus promoting the cross-fertilization (Moen et al., 2012) of knowledge practices across institutions and communities. Finally, IT enables the co-creation of knowledge artifacts by mediating epistemic, pragmatic, social, and reflective aspects of work.

The system is one of the core elements of this study, as it is intended to promote the knowledge elicitation of employees as co-creators of MLE. The system consists of an IT-supported co-creation process that can be accessed through any standard browser and is therefore device independent. The system is based on the existing content management system (CMS) WordPress, using the Frontier Post[1] plugin to add a review process for the front end and the Buddypress[2] plugin to create and organize different membership levels. An overview of the system is shown in Fig. 1.

The system includes several features to support employees in co-creating and storing MLEs in a coherent way (Fig. 2). In the first step (Knowledge Categorization), learning material is tagged to a work process and individual process steps to facilitate retrieval and the development of learning arrangements that cover entire work processes. Thus, (A) the employee must select the appropriate work process, (B) select a process step, (C) select whether the MLE explains a standard procedure or troubleshooting, and (D) select a unique name. After the assignment, the actual content development for the MLE follows (second step—Knowledge Dissemination). By asking guiding, clear but open questions, the creators are encouraged to interact with the platform and reflect on their work (Pérez-Sanagustín et al., 2015; Quadir et al., 2022). This reflection in action stimulates the cognitive processes of

1 https://wpfrontier.com/
2 https://de.wordpress.org/plugins/buddypress/

the participants and should promote knowledge elicitation (Schmidt, 2007). The documentation is divided into sub-steps. First, employees describe the process steps in writing. This description can be supplemented with photos, which in turn can be expanded with text and graphic elements. Every sub-step is structured in this way. It is important to note that there was no limit to the number of possible sub-steps, as this further accommodated the scope for knowledge dissemination by individuals. Finally, in the third step (Feedback and Review), participants see an overview of the MLE and can redo their entries. Each MLE is published in the CMS system, but is only visible to the creators. To ensure sufficient quality, MLEs are reviewed by supervisors after submission by the employee. Supervisors can comment the material and return it to the employee or correct the material themselves.

3.3 Background and setting

In order to evaluate the effect of the IT-supported co-creation system on the knowledge elaboration of the co-creators, we created a pre-post evaluation in an inter-company vocational training center. The center was chosen because it had the necessary facilities and had previously used adequate teaching concepts that were identical or very similar to work process integrated learning arrangements in companies. In addition, this setting allowed us to gather a larger group of participants, since evaluation directly in manufacturing companies often involves interruptions in production. The CNC (Computerized Numerical Control) and metalworking department of the training center focuses on training employees for production-related professions, such as machine operator or precision mechanic. The intervention begins with a theoretical introduction, followed by a practical session integrated with the work process in the workshop. For this study, we focused on work processes that are highly dependent on one or more machines or tools, facilitating the process of diverse media production for the participants.

3.4 Sample

Participants, i.e. co-creators, in this study were (N = 8) master craftsman trainees (two tool mechanics, two mechanical and plant engineering trainees, and four precision mechanics; all state-recognized training occupations in the German vocational training system). The participants were selected because of a particular overlap in the curricula of the first-year trainees, i.e., the subject matter of initial start-up of CNC lathes and locating and setting a zero reference point. Among other common topics, this work process was identified as a suitable MLE case during previous expert interviews with teaching staff. The interventions took place on two different dates, one in Q1 2020 (tool mechanics and mechanical and plant engineering trainees), the other in Q3 2020 (precision mechanics trainees), in suitable workshops of the inter-company vocational training center, which provided a learning context similar to real manufacturing environments.

3.5 Task and co-creation design

At the beginning of the workshops, teams of two are formed to ensure that participants perform both a demonstration of a work process (as the content of the MLE) and its documentation using tablet computers. In addition, this arrangement facilitates collaborative work in the creation process, which is generally associated with a positive influence on the quality of the results (Howson & Weller, 2016), and promotes the inclusion of all employees (Bovill et al., 2016), which may further encourage knowledge elicitation and elaboration (Hämäläinen et al., 2008). The pre-post design of the evaluation is shown in Fig. 1 and described below.

The workshop itself consisted of three phases. (1) In the preparation phase, the participants received an initial briefing on the workshop procedure, the concept mapping method and the platform itself. In this way, the participants developed a basic understanding of the co-creation process of learning materials and the underlying methodology. An example task (making coffee) was used to illustrate the process in a playful way (see Appendix Figs. 6 and 7). At the end of the preparation, the participants created CMs about the initial startup of CNC lathes as well as locating and setting a zero reference point to record a baseline of elaboration in terms of work process knowledge. (2) In the main part of the workshop, the creators used the IT-supported co-creation platform to co-create learning materials in groups of two. They were free to decide how to integrate the creation process into their work. During the process, one participant managed the workflow and the other created the MLE. In the last step of the workshop (3), the creators had to revise their CM. By comparing the two states of the CMs, we want to determine whether the collaborative development of MLEs benefits (expert) knowledge elaboration.

3.6 Measurement and analysis approach

3.6.1 Concept maps

To assess the influence of the process on the individual co-creator's knowledge elaboration, we used CMs to distinguish types of elaborated knowledge by examining semantic properties and expert knowledge features embedded in them (Chang et al., 2022). As two-dimensional representations of knowledge structures, CMs depict a network of concepts (framed one- or multi-word terms) as nodes and the relationships (labeled directional arrows) between concepts (Cañas et al., 2005). Pairs of two concepts and a connecting relationship are called propositions (Ruiz-Primo, 2000) and constitute the smallest identifiable knowledge element. Typically, CMs can be distinguished from similar methods of knowledge representation, such as mind maps, by the hierarchization of concepts (Novak, 2002). With this in mind, our use of concept mapping to reveal different types of knowledge is based on the approach of Kinchin et al. (2019), who use a translation and plotting procedure with roots in legitimation code theory (Maton & Chen, 2016) for evaluative purposes. This approach seems fruitful to explain the qualitative differences in knowledge structures modified or acquired through IT-supported co-creation activities, as it takes into account the contextuality of knowledge construction and activation, which is paramount in VET. In addition, we examined individual CMs on the basis of structural and content characteristics derived from expertise research (Chi, 2006a) and CM literature (Cañas et al., 2005) to justify further adjustments to the co-creation process.

3.6.2 Data generation and procedure

Using Kinchin et al.'s (2019) three-step process for data generation for the semantic level, map construction and revision (step one) was performed by the creators of the MLE. The linking phrases present in the participants' CMs were translated into expressions of semantic gravity and semantic density (step two). The resulting codes were plotted on the semantic plane (step three). In addition, hierarchies and content knowledge represented in individual CMs were analyzed as relevant features of expert knowledge (Cañas et al., 2005; Chi, 2006a).

3.6.3 Map construction and coding of propositions

In order to properly relate our qualitative approach and the results of the concept mapping to the existing literature and further research, we used an additional framework of CM assessments based on the meta-evaluation of Ruiz-Primo and Shavelson (1996). The task was designed as a single task in which no components of the map (concepts, relations, hierarchies) were given. There were no additional tasks other than the CMs. The role of the mapper was assumed by the creator of the MLE. Subsequently, following Kinchin et al. (2019), the evaluation of the CM results was performed at the propositional level, including the accentuation of crosslinks (Ding, 2009) for their role in the morphological aspects of concept mapping and the content of the proposition. Differences between pre- and post-CMs are located within their respective hierarchies (upper, middle, and lower levels). As there was no grading/scoring intention behind the evaluation, no weighting was done. After the IT-supported co-creation process of MLE was completed, the second concept mapping phase was conducted under the same conditions, but the creators could decide whether to add to their existing map or to create a new one.

By transforming the relations between concepts into descriptions of their semantic density (SD) and semantic gravity (SG), the CMs could be translated into comments on the knowledge types represented in them. SG serves as a dimension of context specificity, distinguishing between sensible (SG+) and strong (SG++) ties of the articulated knowledge to a particular context, as well as generalizable (SG-) and very generalizable (SG–) views of the represented topic. The translations of the SD dimension outlined the degree of meaning condensation, distinguishing between simple, everyday language (SD- or SD–) and the use of technical terms with a significant amount of meaning (SD+or SD++) (Kinchin et al., 2019). The translation devices shown in Tables 1 and 2 contrast the eight different characteristics and their associated coding criteria. Two of the authors involved in this study served as translators (raters) after a coding consensus was reached.

Table 1 Sematic gravity factors

Allocated Code	Criteria
SG–	• Co-creator uses abstract concepts and integrates them with general everyday knowledge that is applicable in a wide range of contexts
	• Propositions might unify scientific principles by highlighting links between ideas
SG-	• Co-creator uses concepts from different sections of formal process specifications
	• Propositions relate to ideas that are applicable to a broader context
SG+	• Co-creator uses scientific concepts that are embedded in practical contexts
	• Propositions might express an example that is used commonly in everyday life
SG++	• Co-creator uses scientific concepts that only require a recall of the definition or rule
	• Proposition expresses the knowledge that is located in a specific process specification

Table 2 Semantic density factors

Allocated Code	Criteria
SD–	• Co-creator uses general everyday language, and there is no theoretical knowledge needed to form a proposition
	• Forming a proposition does not need understanding or interpretation of scientific terminology
SD-	• Co-creator needs to interpret only one concept to form a theoretically/scientifically correct proposition
	• Proposition does not need to be manipulated to fit the given context (the whole CM)
SD+	• Co-creator uses specialized scientific concepts
	• Employee needs to identify concepts before they can be interpreted to form a meaningful proposition
SD++	• Co-creator needs to identify concepts (multiple steps required) to form a meaningful/scientifically correct proposition that interacts with the whole CM

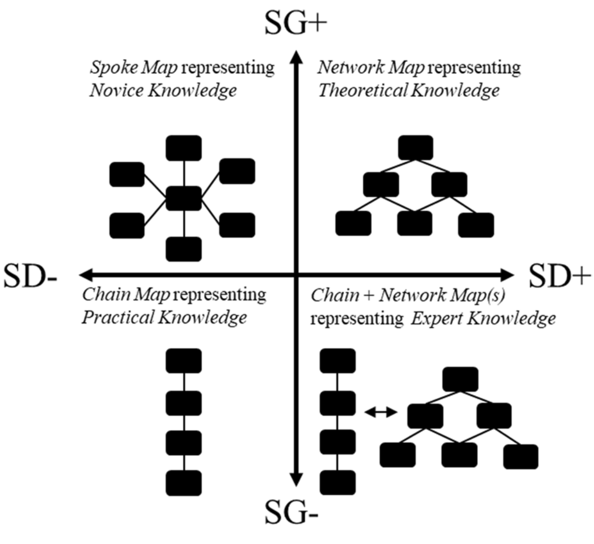


Fig. 3 Semantic plane with prototypical CM types adapted from Kinchin et al. (2019)

The translation was performed using MAXQDA 12, a qualitative data analysis software, with SG and SD as top categories and their respective complexions as subcategories. Due to the two-dimensional nature of Kinchin et al.'s (2019) approach, the propositions required two codes each, resulting in overlap when displayed simultaneously in MAXQDA 12. Once the relationships were transformed, the codes were plotted on the semantic plane (Fig. 3), indicating which knowledge types and map structures predominated. As this study employed a pre-post design, the results from both CM phases were incorporated into learner-specific plots and an aggregated plot. The latter guided the initial examination of participants' CM performance, as shown in the following section.

4 Results

In this section the results obtained from the data analysis are carried out. The results are arranged according to the semantic plane results and their plotting, as well as according to the CM characteristics.

4.1 Aggregated results on the semantic plane

Overall, the CMs show numerous propositions that indicate the existence of practical and expert knowledge of the creators. An example MLE result and a corresponding coding of the CM is shown in Fig. 4.

It is noticeable that strictly theoretical knowledge, although necessary for the development of expert knowledge, was hardly made explicit and the elicitation

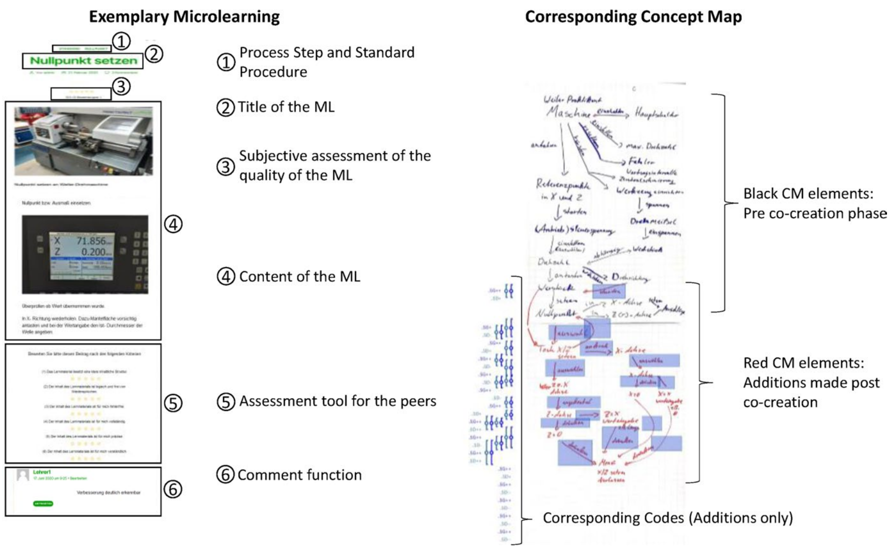
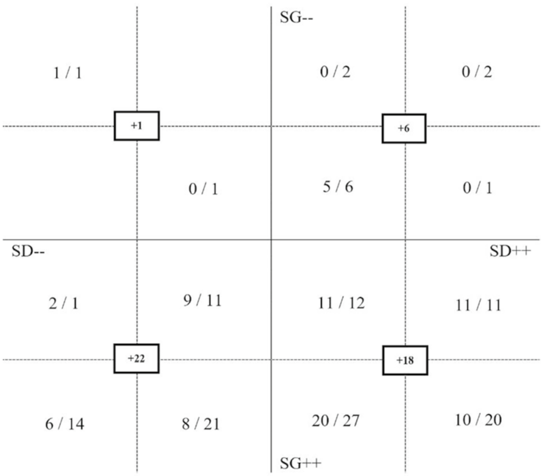


Fig. 4 Developed MLE and CM with the corresponding codes



x/ y	Number of propositions "before/after" the intervention
□	Difference in the number of propositions before and after the intervention within the four main quadrants (Novice-, Theoretical-, Practical- and Expert Knowledge)

Fig. 5 Aggregated plot of coding results showing changes in knowledge elaboration with an emphasis on expert knowledge (high SG/high SD) and practical Knowledge elicitation (high SG/low SD)

of novice knowledge was negligible. The aggregated plot (Fig. 5) shows that the changes in the CMs occurred mainly in the SG.

The increase in SD propositions was less clear: a similar number of propositions were added in the SD- and SD– domains as in the SD + and SD + + domains. Regarding practical knowledge, the number of propositions almost doubled, and expert knowledge elicitation also increased significantly. The structure of the CM is similar to the structure of the proposed design of the MLE in the co-creation system, which may be a reason for the high number of practical propositions, since the system promotes the representation of knowledge in the form of a step-by-step sequence. However, the differences before and after the intervention changed the relationship between the number of experts and practical knowledge propositions.

4.2 Analysis of CM characteristics

Table 3 lists the heterogeneous evolution of the structural characteristics of the creators' CMs and complements the plot of propositions with aspects of relative differentiation between novices and experts that help optimize the co-creation processes. Changes in knowledge representations have been examined primarily in terms of hierarchical manipulation (Chi, 2006a) and content (Cañas et al., 2015).

Knowledge extent For the number of propositions as a characteristic of knowledge extent and a unit of measurement for it, a positive development could be derived

Table 3 CM characteristics (Tool Mechanics (TM), Mechanical and Plant Engineers (MPE), Precision Mechanics (PM))

Participant	Plotting results			Hierarchical manipulation	Subsumption of open codes
	Map Type—pre	Map Type—post	# of Propositions pre / post	Localization of Changes	Propositional content
TM1	Chain	Network	13 / 12	Entire Map Change	N/A
TM2	Chain	Chain	15 / 22	Lower Levels of Hierarchy	Machine Input
MPE1	Network	Chain	8 / 15	Lower Levels of Hierarchy	Machine Input
MPE2	Chain	Chain	4 / 8	Lower Levels of Hierarchy	Machine Input
PM1	Chain; Network	Chain; Network	13 / 18	Lower Levels of Hierarchy Cross-Links from upper levels to mid- and lower levels of Hierarchy	Execute Program / Test run Conditions
PM2	Chain; Network	Chain; Network	17 / 32	Lower Levels of Hierarchy	Machine Input
PM3	Chain	Chain; Network	8 / 15	Middle and Lower Levels of Hierarchy Cross-Links from Middle Levels to Lower Levels of Hierarchy	Machine Input Recourse to topic
PM4	Chain	Chain	5 / 10	Middle Levels of Hierarchy Lower Levels of Hierarchy	Execute Program/Test run Material properties

from the pre- and post-results. In the case of co-creators with only a few propositions after the first CM phase, the comprehensibility of the work process increased significantly by expressing more process steps in the MLE. This was directly related to the increased focus on practical knowledge elicitation (MPE1, MPE2, PM3).

Organization The more pronounced emergence of practical knowledge in the aggregated plot and the changed ratio between practical and expert knowledge was the result of some additions made to the CMs, which mainly revolved around machine-specific input or handling procedures of the initial start-up and process steps for configuring the zero reference point. These changes took place primarily on the lower levels of the CM hierarchies (TM2, MPE1, MPE2, PM2). The importance of earlier representations, which were very abstract, was greatly reduced, especially for MPE2, which had a less elaborate CM prior to the co-creation.

Knowledge depth The depth of knowledge is most closely represented by the plotting results, as Kinchin and colleagues' procedure (2019) worked with the levels of abstraction and concreteness on a semantic level. Here, like with the additions of very specific work process steps to the lower hierarchical levels, the loss of the degree of abstraction in the representations can also be mentioned, which is reflected by the roughly equal increase of propositions in SD–/SD- and SD+ +/SD+.

Consolidation and integration Only limited statements can be made about this. However, it is noticeable that despite the direction towards more practical knowledge, there was an increased formation of networked structures among individual participants. Among these participants, a change took place in the middle hierarchical levels with the use of cross-links that did not refer to the specific machine (PM1, PM3, PM4).

5 Discussion

In this study, we answered the question to what extent the implementation of an IT-supported MLE co-creation system enhances knowledge elaboration among co-creators. Contrary to our hypothesis, IT-supported co-creation had a positive effect on the elicitation and elaboration of both expert and practical knowledge, as evidenced at both the semantic and structural levels of CM changes. By this means, this qualitative and rather exploratory study in the field has one overall contribution to the literature: We show that the developed IT-supported co-creation process for MLE in work-process-integrated learning scenarios has a considerable impact on specific kinds of knowledge elaboration. By utilizing an innovative CM approach for VET research (Chang et al., 2022) we were able to identify differences in the knowledge structures of the employees and, thus, investigate the effects of the co-creation process. With the combination of Kinchin et al.'s (2019) semantic plane approach and Chi's (2006a) hierarchies of knowledge, we provided a novel perspective on co-creation in VET. Further, our findings suggest that co-creation systems can support the development of cross-links between knowledge structures (Ding, 2009), including the integration of previous knowledge in the ML, resulting in knowledge elaboration of co-creators (Kalyuga, 2009; Ritchie & Karge, 1996). In the following, we discuss this overall contribution and the findings of the study in detail.

Our findings indicate that the promotion of practical knowledge shown in the aggregated plot of SD and SG can be a result of the guidance the co-creators were given by the IT-support system. The system maps the existing routines of the work process (Pentland & Feldman, 2008), which indicates an increase of (practical) knowledge elaboration. As we observed that the developed CMs and MLEs represent a step-by-step sequence of the work process in practice, the ostensive but especially performative aspects of the work process were outlined by the study participants (Wolthuis et al., 2022). Therefore, the design of the researched IT-supported co-creation system could reinforce the elicitation of practical knowledge in particular. In turn, knowledge elicitation could provide positive effects on the knowledge elaboration overall, not exclusively expert knowledge.

In relation to the co-creation process itself, our findings indicate that it should not overly emphasize sequences of work-steps but rather open up the mode of response to capture the individual interpretations of work processes (Clancey, 2002, 2006). Especially for the case of technical knowledge, this could encourage the use of according terminology, e.g., by utilizing just-in-time prompts (Koszalka et al., 2019; Wu et al., 2018) delivered by the platform. Negotiating the quality of MLE content across participants may become more extensive as a result. At the same time, our qualitative observations indicate that process structure through guiding questions in the development of the MLEs is still necessary. As co-creators usually lack didactic competencies, such a structure prevents that co-creators are overwhelmed by the process itself. Thus, our findings also highlight that the interaction with the system itself (Engelmann et al., 2014; Pérez-Sanagustín et al., 2015; Quadir et al., 2022) and fellow co-creators contributed to an exchange of different perspectives in situated learnings environments (Hämäläinen et al., 2008; Pérez-Sanagustín et al., 2015).

With the help of the detailed analysis of the domain-specific content, we discovered the repeated appearance of the CNC lathe as a contextual factor in the creators' post-intervention CMs, with only limited integration into the CM structure already present at that point. This led to an overweighting of practical knowledge in the translation and plotting of propositions, thus indicating an unfavorable result of the IT-supported co-creation process (Pentland & Feldman, 2008) at first glance. Nonetheless, by promoting the integration of contextual information as examples during knowledge elicitation (Ruiz-Primo & Shavelson, 1996), generalizable and context-specific aspects of work processes could be captured in MLEs.

The results also suggest that the expert handling of changes in one's own mental representations (Ericsson & Kintsch, 1995) manifests itself structurally through a broader activation of knowledge, reorganization of knowledge across hierarchical levels (e.g., by employing cross-links), and more diverse representations in terms of content (Cañas et al., 2015; Lee & Clariana, 2022). Furthermore, the process optimization encourages the inclusion of theoretical knowledge to associate work-process steps across different hierarchical levels and eventually different work processes to promote knowledge consolidation and integration.

6 Practical implications, limitation and future research

To leverage the potential of IT-supported co-creation systems for MLE content, practitioners should consider several aspects when integrating co-creation practices into their instructional designs. Providing co-creators with necessary resources is essential for facilitating these processes in the first place. Obvious but often neglected aspects relate to the relevant hardware, e.g., rugged tablets or smartphones for industry use instead of bring-your-own-device to also consider security and privacy aspects. Further, participants should be empowered through training and simply time resources for these processes. By considering concepts such as lead users, organizations could engage these co-creation processes through key educators in the organization. This is especially relevant for ensuring that the content is adequate in terms content quality. Findings from internal crowdsourcing could provide valuable starting points for practitioners to broadly implement high-quality co-creation into organizations and VET processes (Zuchowski et al., 2016).

Considering the empowerment of co-creators, motivation is also a key aspect to foster a conducive environment for co-creation and communication among participants. This might include considerations such as gamification to simply make co-creation processes "fun" (Schöbel et al., 2020). The role of facilitators to overcome power dynamics among co-contributors is also important to consider. Research from collaboration engineering provides valuable examples of how digital artifacts themselves address power dynamics (Briggs et al., 2013), for example by simply adding layers of anonymity to engage collaboration (Briggs, 2006). In addition, digital facilitators could guide the co-creation process, provide feedback and encouragement, and mediate conflicts or disagreements (Seeber et al., 2019). By additionally relying on collaboration scripts from education (Kollar et al., 2006), we could seek to overcome power dynamics in practice, which entails a culture of trust, respect, and collaboration, to avoid hierarchical or competitive relationships among co-creators.

The present study is not without limitations. First, we are not in a position to determine the long-term effects of the co-creation of MLEs on knowledge elaboration for VET. Additionally, since only one work process was employed for co-creational MLE development, no statements can be made about the dependence of the domain-specific content and knowledge elicitation. Second, the small sample size of eight participants prohibits the use of the approach taken by Kinchin et al. (2019) for the quantitative evaluation of IT-supported co-creation. As we worked with an inter-company vocational training center in this study, fully replicating the detrimental effects of work contexts (sounds, etc.) was also not possible. Nonetheless, we acknowledge this limitation consciously to provide a high-degree of ecological validity to our findings. Third, the promotion of practical knowledge can be a result of the CM task itself, reinforcing the representation of work processes step-by-step (Metcalf et al., 2018; Ruiz-Primo & Shavelson, 1996). The limitations mentioned have already been addressed in the continued development of the platform, as well as in further workshops of a larger study at the time of writing this article. Methodologically, it should be added that self-imposed limitations due to structural/morphological map characteristics and decreasing commitment in the CM task can be assumed for the post-intervention phase.

Future research should focus on just-in-time support features, such as chatbots and prompts, while overall designing a less rigid procedure of work process documentation (Bittner et al., 2021; Thomaz et al., 2020). At the same time, these approaches accommodate knowledge elicitation of expert knowledge, as they can be better adapted to the individual context of the employees as well as to their working conditions.

7 Conclusion

Our study answered the question of how an IT supported co-creation system can support the individual knowledge elaboration of expert knowledge in VET. With our study in a vocational training center, we were able to show that the use of IT-supported co-creation systems in the development process of MLE has a positive effect on the knowledge elaboration of employees, more precisely by revealing how the elicitation of expert knowledge has improved compared to other kinds of knowledge. The high number of practical propositions currently implies that our IT-supported co-creation system can support the development of practical knowledge in particular. The co-creators showed an increased knowledge extent and a better organization of their maps after working with the co-creation system. The study provides empirical evidence for the usefulness of co-creation systems for the development of MLE and subsequent effects on knowledge elaboration of co-creators.

Appendix 1

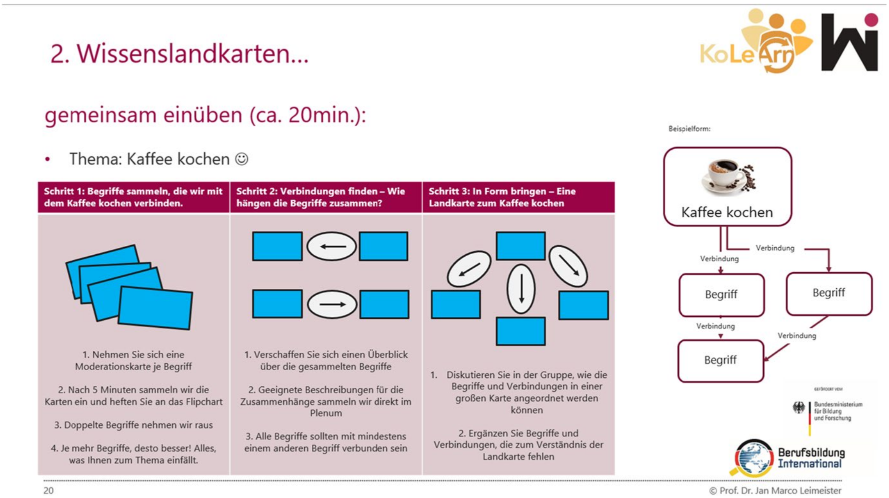


Fig. 6 Task description and individual steps for concept mapping as an introduction to the method with “coffee making” as an exemplary task

Fig. 7 Result of the introductory concept mapping task with "coffee making" as an exemplary task

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Data availability The generated and analyzed data is not publicly available due to privacy concerns.

Declarations

All evaluations were conducted under the European General Data Protection Regulation (GDPR) and the data processing rules of the University of Kassel to protect the personal data of the participants.

Informed consent All study participants signed an informed consent.

Conflicts of interest The authors declare that there are no other potential conflicts of interest.

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Authors and Affiliations

Marian Thiel de Gafenco[1] · **Tim Weinert**[2] · **Andreas Janson**[3] · **Jens Klusmeyer**[1] · **Jan Marco Leimeister**[2,3]

[1] University of Kassel, Henschelstrasse 2, 34127 Kassel, Germany

[2] University of Kassel, Pfannkuchstrasse 1, 34121 Kassel, Germany

[3] University of St. Gallen, Müller-Friedberg-Strasse 8, St. Gallen, Switzerland