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TOWARDS CO-CREATION OF LEARNING MATERIAL IN VOCATIONAL TRAINING

Research in Progress

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Abstract

The complexity of production processes increased during the last years, especially due to digitalization, which results in an increasing need of in-company trainings. Hence, companies use trainings to impart action-oriented knowledge in the work process. However, these trainings are often supported by learning materials that do not reflect the current work situation of the employees because they are either outdated or too general. We are addressing this problem using a co-creation process by enabling employees to generate the materials independently during the work process. Within the framework of a theory-driven design science research approach, we derived requirements from theory as well as from a focus group workshop and a work process analysis to develop design elements for this process. We pay particular attention to the cognitive load (CL) of the employees. The theoretical contribution of our research is twofold: On the one hand, we give insights regarding the effects of the physical environment on CL. On the other hand, we give insights about how to design systems that can avoid CL within knowledge generation processes. In this way, we help practitioners to design systems that consider the CL of employees.

Keywords: Cognitive Load, Design Science Research, Co-Creation.

1 Introduction

Over the years, a considerable amount of research has been carried out to determine the effects the increase in complexity of industrial production processes, especially due to digitalization, has on in-company trainings (Filipenko *et al.*, 2019; Meinhard and Flake, 2018; Seyda *et al.*, 2018; Senderek, 2016). These trainings typically draw from established instructional design models, such as the cognitive apprenticeship (Brown *et al.*, 1989), or from more contemporary approaches of social workplace learning (Erpenbeck *et al.*, 2016) to cope with an ever-declining half-life of skills acquired in formal educational settings (Senderek, 2016). One commonality can be pointed out across most of these rudiments that decisively contributes to their success: A thorough work process integration of learning (Dehnbostel, 2008; Howe, 2008). Nevertheless, additionally employed learning material may not support such design models in a meaningful way.

Learning resources used for in-company trainings rarely meet the requirements and characteristics of the individual workplace or, in stark contrast, closely portray specificities of a work process as part of Knowledge Management efforts, thus lacking the didactical foundation to be used for learning in an effective manner (Schmidt, 2007). As part of a previously conducted work process analysis (Spöttl, 2007), dedicated to converting work-process-related documents into learning material, a breakdown of said documents revealed outdated descriptions of production processes and unstructured problem-solving documentations. While primarily pursuing practical learning solutions for manufacturing companies located in China, a focus determined by our work in an international vocational education and training (VET) project, this analysis further substantiates our impression of the inadequacy of these documents, not only for in-company training but for basic Knowledge Management purposes as well. Knowledge Management Systems (KMS) designed to store and disseminate records of work process knowledge (Fischer and Boreham, 2008) that also support employees and their supervisors to take even rudimentary didactical aspects into account are few and far between. The accessibility of such a system, especially in its early stages of deployment, as well as establishing routines of Knowledge Management and learning phases within work processes remain critical for the dissemination of work process knowledge (Sensuse *et al.*, 2018).

However, the impetus to develop learning material that is tailored by and for the employees, especially to provide adequate learning material on demand (Emerson and Berge, 2018), is still prominent, as such co-creational concepts enable companies to benefit from a wide range of established concepts and approaches traceable in the domains of Knowledge Management and VET research, i.e., the adherence to the contextuality of work process knowledge (Becker, 2005), the incorporation and maintenance of basic Knowledge Management on the shop-floor level (Nakano *et al.*, 2013) and eventually the cultivation of communities of practice (Lave and Wenger, 2011) to further improve the quality of their in-company training efforts.

Attempts to address the outlined shortcomings may fail to consider the detrimental effects of the real work environment to engage with Knowledge and Learning Management Systems (Choi *et al.*, 2014). For both practical and scientific purposes, designing a virtual learning environment following recent insights from educational psychology in general and from the Cognitive Load (CL) theory in particular are promising to overcome these challenges, thus enabling companies to exploit the referred benefits of a co-creation of learning material for their respective Knowledge Management endeavors. Following these assumptions, the research aim can be formulated as follows:

RQ: *How should a Knowledge Management System be designed that enables the co-creation of learning material under the consideration of Cognitive Load?*

The purpose of this research-in-progress paper is to derive design requirements for *virtual learning environments* to address potentially detrimental aspects of *real working environments* for the co-creation of learning material. Based on these requirements, design elements are derived that address these requirements. In pursuit of that purpose, a review of literature on CL theory as well as a work process analysis and a focus group workshop were conducted as part of our work in the aforementioned VET project.

2 Theoretical Background

2.1 Knowledge Management Systems

KMS offer the possibility of storing knowledge centrally and making it accessible to other employees (Friedrich *et al.*, 2019). In particular, problems arise when converting tacit knowledge into explicit knowledge during the knowledge generation process in KMS (He and Wei, 2009). Hence, the KMS should map certain routines in the process of generating knowledge (Pentland and Feldman, 2008). Routines can be understood as repeatable and recognizable actions (Feldman and Pentland, 2003). These routines can reduce the CL of employees (Alavi and Leidner, 2001; Parmigiani and Howard-Grenville, 2011) and are therefore beneficial for the knowledge generation process as a whole..

In order to overcome the cognitive overload of employees when storing knowledge, so scaffolds calld scaffolds, an instructional method with roots in social constructivism (Wood *et al.*, 1976), offer a way to control and support interaction with the KMS (Pea, 2004; Janson *et al.*, 2019). Scaffolding temporarily supports the learner with structures and routines during the learning process (Janson *et al.*, 2019). These routines can help to guide learners through the co-creation process of learning material, especially when the learner is involved in the work process. Scaffolds are used in problem-solving scenarios for cumulative knowledge and skill acquisition (Hannafin *et al.*, 2004). Thereby, it could be shown that scaffolds have the ability to reduce the CL of learners (Janson *et al.*, 2019). At the same time, the use of scaffolding in different contexts is widely discussed (Sun *et al.*, 2018; Eryilmaz *et al.*, 2015).

The aim of the KMS in production is to store action-oriented/work process knowledge in the work process. If a problem occurs, the employee must solve the problem in a timely manner. Afterwards the employee has to document the problem-solving procedure in the KMS, preferably according to a predetermined structure. The cognitive capacities required for this process may be lacking due to the ongoing work process or the lack of experience with the KMS (Choi *et al.*, 2014). Thus, structures and guidelines can help the employee to create learning material in the KMS in a time-efficient manner and simultaneously reduce the CL of the employees. Hence, we postulate that scaffolding has a positive influence on the ability of employees to store knowledge in the KMS during the work process.

2.2 Cognitive Load Theory

The CL Theory provides a framework for designing learning materials (Artino, 2008). Especially in the knowledge generation process it is important to consider the cognitive capacities of employees. Moreover, these considerations should determine KMS designs to facilitate effective Knowledge Management and subsequent learning efforts. Otherwise, an information overload can occur (Putz and Treiblmaier, 2015). According to CL Theory, this potentially overburdening experience may occur more quickly during the work process, especially if the knowledge generation and documentation process takes place in the middle of an ongoing work process. With this possibility in mind, Paas and van Merriënboer (1994) explain the resulting CL not only in terms of the *task* (here the production of corresponding learning material during the work process) but also in terms of the *physical environment* in which the task must be performed and the inherent cognitive capacities of the *learners*. The *physical environment* represents the range of physical characteristics in which the task and learning takes place. This includes, for example, the properties of the material, such as color, size, or weight or noise pollution (Vredeveldt *et al.*, 2011). Therefore, environmental factors describe effects on CL that occur when interacting with this environment. *Task* factors describe effects on the CL that arise from interaction with the (learning or creation) task or environment and are related to the characteristics of the task. Examples of this are the overloading of the visual and auditory channel by too much information presented in the task (Mayer and Moreno, 2003). The *learner* describes factors related to the person that lead to increased CL in interaction with the physical environment and/or task. An example of this is a person's IT acceptance (Davis, 1989). This fact must be taken into account when designing a process for the development of learning materials (Artino, 2008). Here, the creation of the material can be understood as a task that takes place in a physical environment, i.e., during the work process (Choi *et al.*, 2014). In many studies, however, the influence of the physical environment is not or not sufficiently taken into account. Consequently, there is a call for a more intensive consideration of the environment around the cognitive load (Choi *et al.*, 2014). The physical environment can have a considerable influence on the CL, especially when creating and storing knowledge during the work process. For instance, in such production-related fields of work, high noise pollution and poor air quality often occurs. Scholey *et al.* (1999), for example, were able to demonstrate that a poor air quality has negative effects on cognitive capacities. Due to the fact that the creation process of learning material for the KMS takes place during the work and the creation process is often not understood as a part of the work (Weinert *et al.*, 2020), the cognitive capacities of the learners are reduced (Artino, 2008). Against this background, we postulate that CL can have a negative influence on the ability of employees to generate knowledge in the KMS.

2.3 Co-Creation of Learning Material

The concept of the co-creation of learning material is based on theories of social constructivism, which refers to learning with and from colleagues (Wegener and Leimeister, 2012). The development of learning material that is created by and for learners is a prominent approach to help people within their learning process (Wegener and Leimeister, 2012). Overall, co-creation is characterized by an increasing blurring between the producer of the learning material and the consumer of the learning material (Oeste-Reiss *et al.*, 2016). Since the creation of high-quality learning materials is a cost- and time- intensive process, the idea of creating learning materials through the learners themselves is a widely discussed approach (Wegener and Leimeister, 2012). Mostly, people feel motivated when they have the possibility to contribute to a product like a KMS (Wegener and Leimeister, 2012). In an educational setting, the creation process has a huge influence on the quality of the produced learning material (Wegener and Leimeister, 2012). In such procedures, the goals and the structure of the creation process can be open or predetermined by an instructor (Oeste-Reiss *et al.*, 2016). However, the created learning contents in the working process for the KMS are mostly situational and consist of small postings, comments, and discussions (Wegener and Leimeister, 2012). Regarding the influence of CL on the co-creation process, a predetermined creation process may help to reduce the CL of the creators and increase the quality of the created learning material. Hence, we assume that a structured predetermined creation process can reduce the CL of the learners in the co-creation process of learning materials.

3 Theory-Driven Design

Within the framework of this work, a prototype that enables learners to actively generate knowledge within the working process will be developed using a Design Science Research (DSR) approach (Peffers *et al.*, 2007). Thereby, we are using a problem-centered approach to design our artifact. The DSR approach enables a structured procedure to derive requirements from theory as well as from practice to design a generalizable artifact (Peffers *et al.*, 2007). Figure 1 illustrates the approach.

A set of theoretical requirements, which are based on the previous considerations, determine necessary design elements for a KMS system that will be developed for and deployed on the shop floor level. Thereby, the platform should enable the creation of valuable content in the work process under the consideration of the limited cognitive capacities of the employees in the work process. Our approach includes three steps to avoid CL in the creation process as well as during the learning process. As a first step, we collect requirements related to the identified aspects of CL (Choi *et al.*, 2014). Thereby, we rely on the knowledge about creation processes as well as on the following learning scenario to derive requirements. On the basis of these considerations, we identify general theoretical requirements for the design of KMS and Learning Management Systems. Step two consists of the collection of practical requirements by means of a work process analysis and a focus group workshop. Eventually, we address the identified requirements using theory-based design elements.

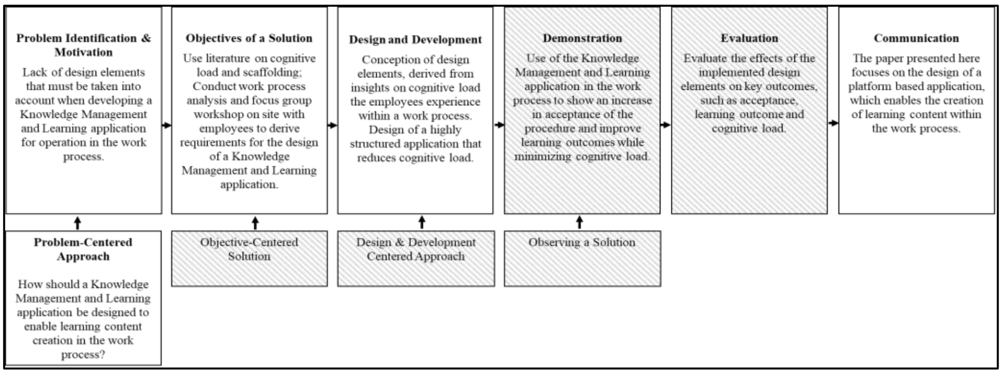

Figure 1: Research Approach for Developing a Learning and Knowledge Platform (cross-striped phases are not addressed within this paper). Adapted from Peffers et al. (2007)

3.1 Requirements from Theory

In this section, we address the goals in the solution phase of the design science approach of Peffers *et al.* (2007) by deriving requirements from the CL theory, as well as from the considerations regarding scaffolding. In doing so, we address the three different causal factors of CL, as described by Choi *et al.* (2014), and try to address every possible theoretical conflict by conducting a narrative literature review. Thus, we draw from literature about knowledge management systems, the peer creation of learning material, scaffolding, and the CL theory. In summary, we can identify five theoretical requirements for the design of the KMS platform in the industrial context in China. The findings are shown in Table 1.

The first requirement (**T1**) addresses the problem that the creation process must be interfaced in the workflow. Since different factors (visual and auditory distractions) can occur in work processes, the platform facilitates content creation at times of little or no disturbances (Choi *et al.*, 2014). For example, an employee can create content at times when he or she is only preoccupied with menial monitoring tasks. The second requirement (**T2**) regarding the environment refers to the design of the KMS platform itself. It should abide to design conformities present in different markets that reflect the expectations of the employees (Choi *et al.*, 2014; Ernst *et al.*, 2016) as well as the accustomed design preferences of the employees.

Cognitive Load Factors	Derived Requirements from Theory (T)
Environment	**T1)** The platform should take the real-world workflow into account. **T2)** The platform should correspond to the cultural and company-specific design preferences of the employees and the company.
Task	**T3)** The platform should provide guidance for the learner to structure procedure for storing knowledge.
Learner	**T4)** The platform should take the expertise of the employee into account. **T5)** The platform should positively influence the employee's motivation.

Table 1: Requirements from Theory

The requirement (**T3**) for the clear structure of the creation process reflects the need for repeatable routines (Paas, 1992; Parmigiani and Howard-Grenville, 2011) to reduce the cognitive load. As Mayer and Moreno (2003) mentioned, simultaneous addressing of channels (auditory and visual) with different information should be avoided.

Two requirements regarding the consideration of the learner could be identified. The first requirement (**T4**) relates to the person's expertise. The platform should be able to adapt to the level of experience of the employee, especially in the form of additional support during the creation process for less experienced employees (Kalyuga *et al.*, 2012). This notion of experience encompasses the work process knowledge as well as experience in the KMS-centered knowledge generation process. Moreover, elements that improve the motivation of users to generate and document knowledge in the KMS should be implemented on the platform (**T5**) (Putz and Treiblmaier, 2015; Schneider *et al.*, 2018). For example, Putz and Treiblmaier (2015) show that the use of gamification elements can have a positive effect on the CL.

3.2 Requirements from Practice

In addition to the above-mentioned theoretical derivations of the system requirements, in the second part of the solution phase we want to assess the theoretical requirements of the system using practical requirements, which have been gathered in a focus group workshop and in a work process analysis. In order to gain a better understanding of the current work situation of the employees, as well as to maintain the physical environment of the employees in the production context, a work process analysis was carried out as a first step (Spöttl, 2007). Based on these findings, the focus group workshop was held in November 2019 in order to uncover possible further requirements. Hence, requirements regarding the integration of the application into the working process were identified and problems regarding the knowledge generation process were disclosed. Following Greenbaum (2002), focus group workshops are an effective way for participants to generate ideas.

The work process analysis and the focus group workshop took place on the shop floor production of a company in the health care sector in China. Especially in China, employees depend on the in-company trainings, since practical vocational training takes place nearly exclusively there. A special feature is the production under clean room conditions. The workshop was held with three technical employees, who were responsible for the supervision of an automated production line as well as their supervisor. The employees are very experienced in the production process and had an average length of service of 1.6 years. This is particularly high for China, which has an average employee turnover rate of over 20% (Anvari *et al.*, 2014). The supervisor has been working for the company for 8 years.

The overall goal of the workshop was to identify requirements for the system to reduce CL in the work process. The learning platform developed in Germany was translated into Chinese. At the beginning, employees were given the opportunity to familiarize themselves with the learning platform and its functions. Since the workshop took place during the work process, employees were introduced to the platform individually and one after the other. Employees should document their work tasks during the work process using the KMS platform. Thereby, employees could decide for themselves whether they wanted to develop and upload media files (e.g., photos or videos) or just descriptive texts. As part of the creation process, employees had to give a title to the generated content, name the associated work process, estimate the difficulty of execution, and name the necessary prior knowledge for later execution. Following the creation phase, the content was checked, further developed, and released by the supervisor to ensure that the content created was comprehensible and correctly laid out. An overview of the creation process is shown in Figure 2.

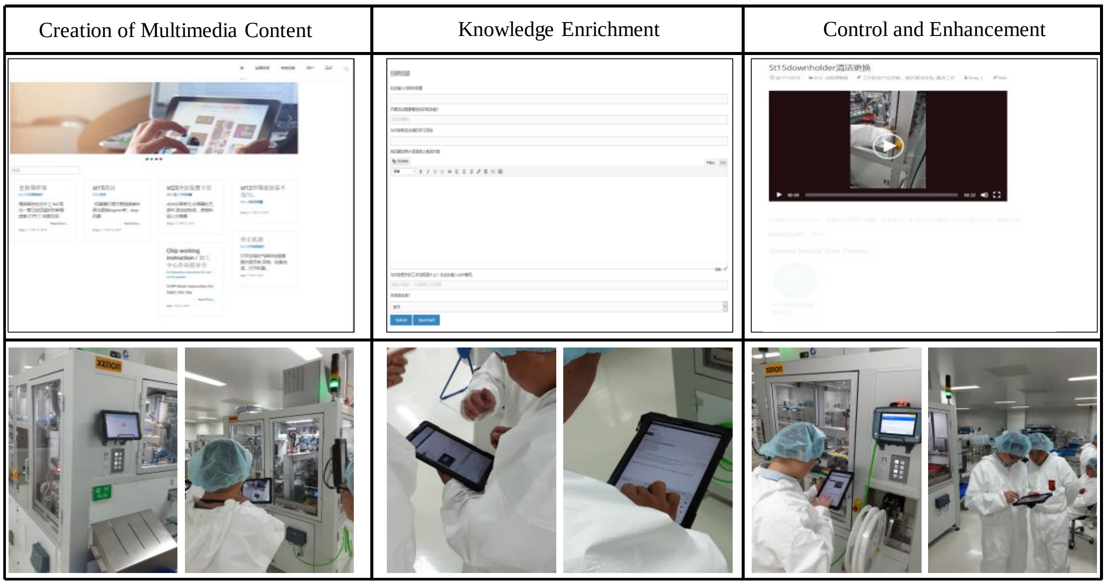

Figure 2: Process Overview of the Focus Group Workshop (some information has been obscured for data security reasons)

After each content was created, employees were asked about suggestions for improvement and problems in the creation process. A total of four requirements were identified. The requirements are presented in Table 2.

Cognitive Load Factors	Requirements from practical application (P)
Environment	**P1)** The platform should provide an opportunity for interaction with the real world.
Task	**P2)** The platform should assist the employee within the creation process. **P3)** The platform should enrich and visualize the content.
Learner	**P4)** The platform should take the employee's experience into account.

Table 2: Requirements from Practice

In digital learning environments there is often a lack of interactivity, e.g., to enable learners to actively participate in the learning process (Winne, 2016). This lack is also mentioned by the participants (**P1**). Especially in training situations, as well as in the creation process, the learners need an opportunity to combine the creation process in KMS with the real world.

Regarding the creation task, two requirements were identified. All of the participants of the workshop mentioned that the creation process is very time-consuming and perceived as costly. Therefore, the platform should support the employees during the creation process (**P2**) to reduce the CL. On the other hand, the employees oftentimes use pictures and videos to enrich their content in the KMS because they have difficulties in describing work related problem cases or the work process itself (**P3**). Therefore, the platform should help the creators to enrich their content with multimedia content.

Due to the learning effects that result from the creation of learning materials in the KMS, the employee needs less support on the platform over time affirming the temporary nature of scaffolding as an instructional method. This effect was confirmed by the users. Moreover, the level of knowledge among the employees differs naturally. During the workshop, employees with more experience could create content more easily than employees with less work experience. Therefore, the platform should take the employee's experience into account (**P4**).

3.3 Design Elements to Overcome Cognitive Load

Starting from the design and development phase of the DSR approach, the following section lists design elements addressing the identified CL theory and scaffolding requirements as well as the practical design requirements. Table 3 shows the identified design elements and the corresponding design requirements.

Cognitive Load Factors	Design Element	Description	Adressed Req.
Environment	Integration of a QR scanner	A QR scanner enables the integration of the physical world in the digital world in the KMS system.	P1, P2, T1, T3
	Company-specific UI	Integration of a company-specific user interface based on the preferences of the target group.	T2,P4
Task	Integration of an information chatbot	Integration of a chatbot, which helps the employee to find relevant information or asks him or her to add further information, if this does not exist yet.	P1,P2,T3
	Structured UI	The interface for entering new knowledge elements is reduced to the essential input elements.	P2,P3,T3
Learner	Integration of an avatar	Integration of gamification elements such as avatars to support employees during the creation process (and beyond) when using the platform.	P4,T4,T5
	User Profile	Integration of a user profile for employees	P4,T4,T5

Table 3: Design Elements for the KMS for the usage within the work process

Environment: Many approaches try to connect the digital world with the real world (Baik, 2012). The use of QR codes is particularly widespread in Chinese culture (Gao et al., 2018). QR codes offer the possibility to enrich the real world with digital content (Baik, 2012). With this in mind, we have *integrated a QR code scanner* to enable employees to quickly and easily store content on specific work processes (P1,P2,T1,T3). During the UI design process, great attention must be paid to the actual user group of the platform and its cultural background, as well as to the specific corporate culture (Meixner and Müller, 2017; Aykin, 2016). The primary users of the platform are employees from the shop floor level in Chinese production facilities. Hence, existing UI concepts of the company and research regarding *culture-specific UI* are taken into account (Reinecke and Bernstein, 2011) (T2,P4).

Task: One of the biggest problems in digital IS systems is the lack of interaction (Winne, 2016). This lack means that employees must be able to independently create and retrieve knowledge on the platform. Against this background, it is important to offer learners support and an opportunity for interaction in order to support this process (Zhang *et al.*, 2016). Therefore, we have integrated an *information chatbot*, which should accompany the employee through the process of creation as well as through the process of finding and using the content (Paikari and van der Hoek, 2018). Chatbots offer a simple way to guide people through a pre-defined process through a text-based chat interaction (Knote *et al.*, 2019) (P1,P2,T3). Vredeveldt *et al.* (2011) has investigated the effects of visual distractions on the CL. They concluded that irrelevant information should be removed to avoid CL in the learning process. We have reduced the complexity of the creation process by specifically asking questions and giving instructions to the employee (Janson *et al.*, 2019) in order to avoid possible distractions in the knowledge generation process. The *UI is restructured* to focus the attention of the user on the creation process (P2,P3,T3).

Learner: The use of gamification, i.e., the use of game elements in a non-game context, has been tested frequently and in different contexts (Thiebes *et al.*, 2014; Alcivar and Abad, 2016). It has been shown that the use of gamification can reduce the CL of individuals (Putz and Treiblmaier, 2015). On the other hand, employees are normally trained within the working process by experts. To pick up on this fact, we are implementing an *avatar* that supports the employees in the creation process (Schöbel and Janson, 2018; Schöbel *et al.*, forthcoming) (TP4,T4,T5). Moreover, van Gerven *et al.* (2002) and Kalyuga *et al.* (2012) have discovered that current knowledge has a major influence on CL. This estimation was confirmed during the focus group workshop, as more experienced employees were able to handle the prototype much more easily and effectively than employees who do not have similar experience. The *integration of a user profile* in which the experience of the users can be updated is considered an important addition to the KMS. On the basis of this information, the system can adapt the creation process by giving more or less assistance and link the creation of content to a certain experience level of the employees (P4,T4,T5).

4 Experimental Design for the Planned Evaluation

In order to evaluate whether the derived design elements lead to lower CL and higher learning outcomes, as mentioned in our research model (see figure 1), we developed an improved prototype that takes the design considerations into account. For the evaluation, we will conduct an experiment in a production setting in China. The evaluation will take place within an exemplary working process scenario. For this purpose, we plan to go to (technical) vocational training schools with adequate shop floors. On the one hand, the target group should be kept as constant as possible. On the other hand, a larger number of participants can be used for the evaluation. Thereby, we plan to divide the students into two groups: one group will use the adapted platform, while the second group will use the unmodified platform. The participants must perform the same tasks on the same machines. Moreover, the participants will be randomly assigned to one of the groups. A pretest with a subset of questions from a cognitive knowledge test is carried out to ensure that the platform can respond to the participants' experience (Gupta and Bostrom, 2013). Furthermore, we measure the CL of the participants (Korbach *et al.*, 2018) as well as several control variables (Pintrich and Groot, 1990). During the experiment, we will ask the participants to complete predefined tasks involving different knowledge-generating and -learning activities supported by the KMS platform. In accordance with our design science research approach (see Figure 1), we will evaluate the CL (Korbach *et al.*, 2018), the motivation (Li and Keller, 2018), and the learning outcomes, like the quality of the created learning content. The CL can negatively influence the learning outcome (van Merriënboer and Sweller, 2005). To measure the learning outcomes, we build on the approach by Gupta and Bostrom (2013) and measure the procedural as well as declarative knowledge acquisition.

5 Expected Contribution and Outlook

The expected contribution of our completed research is twofold. On the one hand, we offer a theory of design and action according to Gregor (2006) and thus a new solution to keep the CL low when documenting action-oriented / work process knowledge. We make a theoretical contribution by systematically developing theory-driven requirements to cope with CL occurring during KMS use. This gives us a deep understanding of how such a creation process needs to be adapted to the needs of the employee. At the same time, we help to understand the distinction between CL in physical environments and CL that occurs when a task is performed. Thus, we also offer practitioners the opportunity to develop better KMSs that can take the CL into account. With the results of this research-in-progress paper, the first considerations regarding the design of the KMS platform are completed. Moreover, we are planning to evaluate our results also in other producing facilities in Europe to exclude cultural effects. After the design elements have been integrated into the platform, the demonstration and evaluation phase of our design science research approach (according to Peffers *et al.* (2007)) begins so as to present completed research.

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