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Knowledge Creation in Requirements Engineering – A Systematic Literature Review

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Abstract. Requirements engineering (RE) is crucial for software development, yet software requirements are often not properly identified or implemented. As the RE process thereby highly depends on human knowledge (explicit and tacit), this problem can in many cases be attributed to the lack of mutual understanding between customers and developers which is caused by diverging domain knowledge. To solve this problem, we conduct a systematic literature review to identify methods associated with Nonaka's organizational knowledge creation theory. We map eight such methods on six common RE problems as we analyze to which extent the methods overcome the associated problems. Although it is not always obvious which problems apply to specific software projects, the identified methods provide an adequate first approach to reduce the risk of potential RE problems, thus making project failure less likely.

Keywords: requirements engineering, knowledge management, knowledge creation, literature review

1 Introduction

Requirements engineering (RE) is crucial for software development, yet software requirements are often not properly identified or implemented [1]. Flaws in RE often cause a variety of problems, probably most importantly not meeting customer needs. Whereas such flaws can be corrected on later stages, these corrections usually come along with signification rework (60 to 100% of the original costs) [1-2].

Another RE problem concerns the (lack of) mutual understanding between customers and developers [3]. Requirements that are incorrectly communicated, perceived, or understood may lead to diverging perceptions on behalf of developers. Causes for these problems include inadequate RE methods or vague and not clearly postulated needs by the customer [1], [4].

RE highly depends on human knowledge which can be divided into two major categories [4-5]: *explicit knowledge* and *tacit knowledge*. The latter one may thereby be *embodied* or *not-yet-embodied*. However, *explicit knowledge* is the only type a person is fully aware of, completely understands and is able to articulate its meaning [4]. The lack of awareness about the two types of tacit knowledge is supposed to

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cause erroneous or incomplete RE. We thus believe that to enhance and sustain the process of organizational knowledge creation helps to address the RE problems. To cope with this issue, we consider the organizational knowledge creation theory [6] which divides the organizational knowledge creation process into four sub-processes. Although a variety of methods exist to implement these processes, their contribution to the RE process has not been scrutinized. To close this gap, we address the following research questions (RQ):

1. Which methods have been proposed that can be applied to RE knowledge creation?
2. To which extent do these methods facilitate and simplify knowledge transfer between customers and developers to overcome common RE challenges in software projects?

To answer these questions, we conduct a systematic literature review [7]. We identify and analyze methods of knowledge creation and determine the degree of their applicability for eliminating common RE problems. We thereby apply organizational knowledge creation theory [6] to categorize the identified methods. Tacit and explicit knowledge play an important role in RE as knowledge is created through their interaction. To facilitate the full potential of (this) knowledge and to solve potential problems, all phases of Nonaka's knowledge spiral should be covered.

With our study, we contribute to theory and practice in the following ways. First, we advance theory of knowledge creation by mapping its methods to common RE problems. Moreover, we identify gaps that need to be addressed to further improve RE. Finally, we provide guidelines that help to solve common RE problems by applying basic knowledge creation methods that dissolve the potential error source of *embodied* and *not-yet-embodied knowledge* as well as flawed communication.

The remainder of this paper is as follows. Next, we refer to common problems in RE, the process of knowledge creation and the interrelatedness of these concepts. We then describe our literature review approach. Subsequently, we present our results. We finally discuss our findings and provide implications for research and practice.

2 Theoretical Background

2.1 RE Problems

Errors during RE inevitably lead to problems in system design and implementation, thus making RE crucial for the software development process [8-9]. These problems are often the result of insufficient requirement analysis. Requirement analysis process includes "deriving the system requirements through observation of existing systems, discussions with potential users and procurers [and] task analysis" [8] and aims to identify and document customer requirements for a planned software [1]. It "has to be organized in close collaboration with all parties involved from outside and inside" [1] and thus requires great coordination and communication effort [3]. Table 1 provides an overview of common problems related to requirements engineering.

Table 1. Problems of requirements engineering [1], [3]

Problems of Requirement engineering	Definition
Lack of information	Lack of information about the needs and requirements of customers and their relevance for the software
Heterogeneous understanding/ Communication gaps	Different views, competencies and experiences resulting in communication problems
Inability to articulate	Difficulties to express or externalize knowledge
Incomplete aggregation	Tacit dimension of knowledge can prevent the complete aggregation of the needs and requirements of the customer
Different project interests	Wrong focus areas and incorrect use of requirements
High degree of coordination and communication	Has to be organized in close collaboration with all involved articles from outside and inside

Throughout the software development process, different views, perspectives and interests need to be aligned among customers and developers [3]. The required communication can thereby be challenging [1], [3]. For instance, customers often determine solutions rather than requirements and their ideas may not reflect the shifting needs of the market [1]. Such problems may be caused by customers' inability to (sufficiently) articulate their wishes as they are in many cases unable to express or externalize their knowledge. Additionally, customers subconsciously have a specific notion of the software to be developed, but lack an adequate technological background. These obstacles make it difficult for the developers to recognize relevant product attributes which are perceived to be important by customers. Moreover, customers may be unable to express all of what they know due to the tacit dimension of knowledge [1]. This tacitness prevents the complete aggregation of needs and requirements of the customer. Furthermore, requirements are often used incorrectly. Instead of generating value for customers they are applied to justify a concrete implementation [3].

2.2 Knowledge Creation in Teams

Contrary to raw data or information, knowledge is personalized and exists only on individuals' minds [10]. When transferring knowledge, it is thus inevitable to transform knowledge into a form that is interpretable by receiving individuals or groups. In this context, two types of knowledge need to be distinguished [6]. Whereas *explicit knowledge* can be articulated, codified and communicated using symbols or language and can for instance be found in books or documents, *tacit knowledge* is about how we do things and therefore difficult to formalize and communicate. Moreover, *tacit knowledge* can be divided into *embodied knowledge* and *not-yet-embodied knowledge* [4-5], [11]. Individuals are aware of their *embodied knowledge* and use it consciously when applying processes and procedures. *Not-yet-embodied* knowledge is characterized by the need of individuals' analytical abilities, reflections, synthetical abilities, logical analysis and creativity. It is reflected in ideas, solutions, innovation and design. Whereas stakeholder's *tacit knowledge* (*embodied* and *not-yet embodied*) about requirements needs to be shared with the developer, *explicit knowledge* can be stored and transferred via documents.

Knowledge management can be defined as a "systemic and organizationally specified process for acquitting, organizing and communicating both *tacit* and *explicit knowledge* of employees so that other employees may make use of it to be more effective and productive in their work" [12]. In RE, it is important to achieve a common understanding by mutually sharing knowledge [6], [13]. Thereby, the knowledge creation process can be seen as a spiral based on both, *tacit* and *explicit knowledge* on the one hand and the interplay between both knowledge dimensions on the other hand [6], [10], [14-15]. Each iteration consists of the following phases: *socialization*, *externalization*, *internalization* and *combination* (cf. Figure. 1).

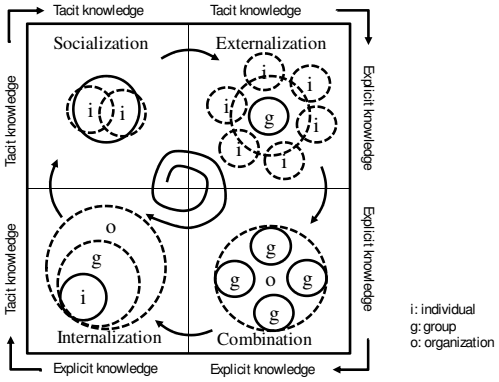

Fig. 1. Nonaka's knowledge spiral [14]

Socialization describes a process where experiences are shared and by this means *tacit knowledge* is created [14-15]. In the field of RE, direct contact between customers and developers is an example for *socialization*. The process of converting *tacit knowledge* into *explicit knowledge* is called e*xternalization* [14-15]. During this process, individuals formulate their knowledge utilizing, for instance, easy understandable metaphors or analogies so that previous *tacit knowledge* of an individual is available for others. During *combination*, *explicit knowledge* is transformed into complex *explicit knowledge* [14-15]. A group uses knowledge from sources outside of the group to combine it with the group's internal knowledge. Usage of knowledge repositories or computerized communications networks can support this process. During *internalization* (also considered as learning), *explicit knowledge* will be transferred into *tacit knowledge* by individuals [14-15]. Usage of documents, manuals or oral stories supports the conversion of knowledge as documenting and verbalizing experiences helps to internalize knowledge.

3 Literature Review

To answer our research questions (cf. section 1), we conducted a systematic literature review [16]. As basis for our search, we selected the following databases:

EBSCOhost, *ProQuest*, *ScienceDirect, IEEE Xplore* and *AISeL*. We thus relied on a multitude of publications, including the extended Senior Scholar's Basket of Journals.

Possibly relevant articles needed to meet the following search pattern in title, abstract, or keywords: (*knowledge management* OR *knowledge transfer* OR *knowledge creation* OR *knowledge worker* OR *knowledge capture* OR *knowledge network* OR *knowledge sharing* OR *knowledge retrieval* OR *information management* OR *information sharing* OR *information transfer* OR *information network* OR *data sharing* OR *data transfer* OR *data management* OR *experience* OR *know-how* OR *communication*) AND (*team* OR *collaborative* OR *groupware*). The search pattern is based on synonyms and differences in spelling and terminology of the main keywords *knowledge* and *team*. Synonyms and related terms were derived by brainstorming and collecting keywords from initially identified articles. We then verified the identified publications in terms of quality and relevance according to our study objective. In order to ensure the transferability of the results into the context of RE only studies referring to knowledge management in teams with an organizational context were taken into account. For the extraction and categorization of the approaches of knowledge management, a matrix approach was applied. At first the acquired approaches were assigned to the suitable phases of knowledge creation [6]. In the final step, we consolidated the approaches and assigned those to match the problems in RE. That way, we provide different solutions to the various RE problems.

4 Results

In the following, we explain each method and their applications to common RE problems. Table 2 provides an overview of this mapping.

4.1 Information Sharing

Knowledge is transformed to information once it is articulated [10]. Thus, methods of information sharing only refer to articulated knowledge. When using codification strategies, knowledge is unified and stored for further use, for instance, using databases or intranets [17], [20-22], [26]. Thus, knowledge can be applied by anyone in an organization regardless of time and space [18], [26], for instance, to be used in upcoming projects [17], [25]. On the one hand, there are centralized approaches, where a centrally located resource can be used by different clients [22], [26]. On the other hand, information sharing can be realized by using P2P to enable team members to collaboratively work on documents [24], [26]. These so-called people-to-document methods are useful to transfer *explicit knowledge* [18], [26] and especially support *combination* [4], [17]. This corresponds to re-use of knowledge. The centralized as well as the P2P approach encourage that knowledge is gathered from various sources. This forms a broader knowledge foundation, making it less likely that a *lack of information* is encountered.

Table 2. Methods and their mapping on RE problems

Method **s= socialization;** **e=externalization;** **c= combination;** **i= internalization**	**Lack of information**	**Heterogeneous understanding / Communication gaps**	**Inability to articulate**	**Incomplete aggregation**	**Different project interests**	**High degree of coordination/ communication**
Information sharing [4], [17–27] s, e, c, i	X	X		X		X
Synchronous and asynchronous communication tools [4], [23–31], [31–39] s, e, c	X	X		X		X
Involvement of external sources [19], [21], [24], [30] s, c,	X		X		X	X
Training [17–20], [30], [40] s, c, i	X	X			X	
Search mechanisms [20–22], [24-25], [28], [40] e, c,	X					X
Face-to-face interaction [4], [17-18], [20], [26–33] s, e, c,	X	X	X	X		X
Work guidelines [17], [19], [24], [40] s, e, c, i	X	X	X			
Creative techniques [17-18], [20], [24], [27–32] s, e, c, i			X	X		

Information sharing can support coordination, for example, when documents with tasks, schedules or meeting agendas are made available for team members [24], [26]. If shared revision of the documents is possible, it is also supportive for communication as the work of individuals can be shared immediately and a related discussion might start. *Explicit knowledge*, referring to the content of documents, can be processed and internalized by accessing, comprehending and reflecting [4], [14-15].

Thereby, creating new ideas and opinions helps to master the *internalization* process. Thus, it is likely that new knowledge is understood and applied. The reflection can be helpful to discover own *embodied knowledge* and make it available for the knowledge creation process [4]. In addition and when writing a document, there is more time to think about articulation than during synchronous communication. This makes it more likely that *tacit knowledge* is expressed and therefore indirectly helps *externalization*, thus solving the problem of *inability to articulate.* However, while writing a document, it is certainly possible to express tacit (not-yet-embodied) knowledge if it reflects ideas and opinions [4]. Thus, it is possible to support *socialization* by reflecting on those documents even if knowledge is only available in text form and cannot be transferred by interaction. If customers' ideas and opinions are understood, they can be helpful to interpret the desired requirements, thus facilitating homogeneous understanding. The problem of its *heterogeneous understanding/communication gaps* would at least be partly eased. These ideas and opinions support discussions, which could even create *not-yet-embodied knowledge* [4] and thus solve the problem of incomplete aggregation.

4.2 Synchronous and Asynchronous Communication Tools

This section illustrates the use of computer-mediated communication tools and their effects on the knowledge creation process [29]. The tools can be divided into two categories - synchronous and asynchronous communication tools - and are one of the most important methods *for socialization* besides face-to-face interaction. Moreover, they are also useful in *combination* and *externalization*. Synchronous communication tools, such as video-conferencing, instant messaging and desktop sharing [29] enable users to communicate at the same time at different places. They bring individuals together in real-time and offer immediate feedback. Asynchronous communication tools such as email, knowledge portals [32], wikis and blogs offer a delayed feedback.

Face-to-face contact can be costly and needs much coordination effort [30]. Especially in cases of long distances between the cooperating parties, the costs of meeting on a regular basis are likely to be high. For this purpose, knowledge transfer in geographically distributed teams should be provided with a "support that facilitates the simulation of face-to-face interaction" [4]. Recent advances in information technology have enabled distributed teams to perform knowledge work effectively without meeting face-to-face [26]. They can be effective against various RE problems, particularly in geographically distributed teams that require an effective and low cost communication [25]. If face-to-face contact is not available to the extent necessary to get the job done, communication tools have to be implemented to support the knowledge creation process [4], [29].

Because a deep understanding of team goals is necessary, teamwork highly depends on communication [36]. In order to reach a mutual understanding within a team, IT support is of high importance [24]. The direct interaction through synchronous communication tools helps to mitigate the *lack of information* problem. Tools like IM (Instant Messenger), Chat or VoIP (Voice over IP) can play an important role for interaction and spreading of knowledge in teams. Asynchronous communication

tools maintain an overtime comprehensible stream of knowledge and improve team interaction. However, in RE it is necessary to get to know the partners and learn their needs, goals and work situations [3].

Communication tools have the ability to reduce the problem of *heterogeneous understanding/communication gaps*, by creating an interpersonal relationship, without meeting each other. Video conferencing for instance has the ability to generate the needed media-richness in order to transfer *tacit knowledge* without meeting face-to-face [29].

4.3 Involvement of External Sources

One option to integrate external sources are power users. Those are selected from user groups based on their experience with and knowledge of business processes [30]. While spending time with developers, the developer's technical jargon and the user's domain knowledge can be shared. This leads to *combination* resulting from the *explicit knowledge* exchange. In case of missing knowledge, the problem of *lack of information* may occur. The close contact and collaboration consequently enables *socialization*. As a result, a common goal is developed and a *high degree of coordination and communication* is reached to prevent *different project interests*.

Experts and consultants are other types of external sources [19]. Using that form, *combination* takes place, as own knowledge is extended based on experts' knowledge to prevent a *lack of information* problem. Before the start of a project, not all required knowledge is necessarily available. Hence, it might be possible that the required knowledge is partly not available and suitable experts need to be identified [21], [24]. By the application of, for example, knowledge repositories and knowledge maps (see *use of search mechanisms*), the search can be simplified [21], [24]. This is especially important if the team is homogeneous as they get new perspectives and new routines from external sources [24].

4.4 Training

Ways to implement training include mentoring, lectures, lessons, audits, classroom training, apprenticeship training or power users [17], [19], [30], [40]. The distinct training approaches differ regarding their empowerment to share *tacit* and/or *explicit knowledge*. While traditional classroom training is deemed an effective method to transfer *explicit knowledge*, other approaches like apprenticeship are better suited to share both *tacit* and *explicit knowledge* [30]. Training is one of the most important methods for *internalization* as it is closely related to learning and *internalization* is basically deemed as learning [14-15]. As new information is transferred (*combination*), understood and internalized and can thus be converted to requirements, training is an effective means to solve the *lack of information* problem. It is also a social process and thus facilitates the sharing of common mental models through dialogs and activities [20] leading to *socialization*. In addition, it is possible to develop inter-individual relationships [30]. By strengthening these relations, it is more likely that project goals are better aligned in the future helping to overcome *different project*

interests. Training may improve mutual understanding, as certain terminologies are clarified or mental models are shared and the problems of *heterogeneous understanding/communication gaps* might be solved. On the one hand, developers could better understand user requirements. On the other hand, training with prototypes gives users an understanding of the system and developers' interpretation of requirements [30].

4.5 Search Mechanisms

Search mechanisms are mainly concerned with the issue to retrieve specific knowledge and to simplify its identification. IT support is indispensable in this process. Thus, IT represents the foundation for the following examples of search mechanisms. Assigned to Nonaka's knowledge spiral, search mechanisms can help in the *combination* and the *externalization* phase of the knowledge creation process due to the fact, that only *explicit knowledge* can be created through search mechanisms. One example for such search mechanisms are knowledge maps, which can be understood as a kind of catalogue or index in which for instance an employee's knowledge, know-how, and expertise are managed and made available for searches [21].

Another search mechanism is the peer-to-peer (P2P) approach, which is presented as a network or network-based computing model. Applying this approach, it is possible to mutually provide and access knowledge among the network members [22-23].

Also assigned to the search mechanisms are patterns [40]. These patterns are described as "a powerful mechanism for […] information-to-knowledge conversion" [40]. They consist of several elements which allow readers to decompose knowledge into its various parts and then to create or assemble a suitable solution for her/his problem out of these decomposed parts [40]. The use of search mechanisms helps to counter two of the identified RE problems. First, it helps in case of *lack of information.* Second, it eases *high coordination and communication* efforts.

Knowledge maps and patterns are predestined to encounter the problem of information lacking. Both organize the knowledge in a way that it can be easily and quickly retrieved and used [21], [40]. Applied to RE, specifically on the interaction between developers and customers, they help gathering all necessary information about the needs and requirements of the customers. To counteract the high degree of coordination as well as the limited contact with customers, developers and customers can rely on the P2P approach. With the help of P2P networks, RE will be organized in close collaboration with all parties involved and the communication and sharing of knowledge can be eased [22-23].

4.6 Face-to-Face Interaction

Face-to-face interaction enables a direct person-to-person knowledge transfer which can be crucial for the creation of knowledge [17]. Especially *socialization* works best with social interaction or demonstration [20]. Moreover, face-to-face interactions can support the *externalization* and *combination* phases of knowledge creation.

There are various activities to implement face-to-face interactions such as project meetings, work related discussions or simple face-to-face conversations during pro-

jects [4], [18]. Groups that use face-to-face communication have access to a number of verbal and non-verbal cues that are important for determining the underlying preferences, positions and emotional experiences of other team members [28], [41].This may for instance help to align the understanding of the specific attributes of the final product. Consequently, using face-to-face methods in RE might help to reduce the problem of a *heterogeneous understanding/communication gaps*. In the same way, the close interaction achieved by direct face-to-face contact supports the creation of knowledge by building social ties. It also helps team members to gain trust and credibility as well as to build and sustain social networks which are crucial for a successful collaboration [27], [30-31]. Thus, the problem of *different project interests* may be solved. Other activities of *face-to-face interaction* such as discussions may support triggering of unconscious *not-yet-embodied knowledge* [4]. This effect reduces the *inability of the customers to articulate the requirements*. Additionally, creative ideas are the result of discussions and interactions at the conscious level, resulting in *combination*. "Interaction among individuals is an important factor for innovation which, is a result of immediate concepts formation within the individual's consciousness" [4]. These resulting ideas from the knowledge creation process with face-to-face interaction might generate the specific product attributes that provide satisfaction for the customer. Close contact, that is, regular meetings with the customer, might help to mitigate the problem of a *lack of information* and *high degree of coordination and communication*.

4.7 Work Guidelines

In addition to the above-mentioned methods, there are work guidelines that facilitate the creation of knowledge in teams, or rather standardize it. These work guidelines can create *explicit* as well as *tacit knowledge* and thus can be classified in all four categories of Nonaka's knowledge spiral. Work guidelines are primarily principles or practices that help to successfully distribute knowledge. One type of such work guidelines are the previously presented patterns (cf. section 4.5). Since it is strictly defined of which elements the patterns consist and how they should be drawn up and filled, patterns can be seen as a type of work guideline [40]. Also among work guidelines are best practices for communication norms through which a common understanding should be established regarding aspects like goals, objectives or task requirements [24]. Best practices that help to create such common understanding are for instance the explicit communication of each other's areas of shared understandings or the use of explanations without local jargon. Another work guideline approach is the model of knowledge processes in organizations by Geisler [19]. This model consists of four modes or stages: generation, transfer, implementation and absorption. Each stage describes another condition in the knowledge process. With all four stages terminated, the knowledge process is complete. Additionally, uncomplicated and often applied tools like checklists, templates, methodologies, procedures and previous project documents are also considered as work guidelines [17]. All these approaches and methods are examples for work guidelines that should help to create knowledge and to

transfer it between team members. To prevent *lack of information,* different work guidelines can be applied. One of them are the above mentioned patterns.

Another approach to encounter this problem is the model of knowledge process in organizations [19]. If the four stages of the model are followed as proposed by Geisler [19], *lack of knowledge* should be eliminated especially in the generation stage in which *explicit* as well as *tacit knowledge* is gathered. In order to solve the problem concerning the *inability to articulate* ones needs and to avoid the lacking of knowledge, patterns can be used as well. The fact, that patterns support decomposing knowledge [40] helps to retrieve and understand knowledge better and eases the articulating needs. Next to the patterns, Geisler's model of knowledge process [19] can help counteracting these two problems. In the implementation and in the absorption stage of the model, newly gathered knowledge is integrated with the existing knowledge [19]. One last problem that work guidelines can counteract is the *heterogeneous understanding/the communication gaps*. Here, best practices of communication can be applied since their goal is to create a common understanding [24].

4.8 Creative Techniques

Creative techniques encourage knowledge exchange in teams and call for team members' creativity. Thereby, they help to create *explicit* and *tacit knowledge* and can thus be assigned to all four categories of Nonaka's knowledge spiral.

The storytelling method is hereby one of the most common form of creative techniques. It is a facilitator of knowledge sharing within a group of people [31]. Applying this method, knowledge or experience concerning past or on-going projects is presented in form of stories or narratives that should facilitate team members to understand and to internalize the knowledge [17]. Thereby, storytelling is especially suitable for transferring *tacit knowledge* [30].

An equally common approach of creative techniques is the use of boards of any kind, such as electronic whiteboards, smartboards or system storyboards [20], [24], [28], [39]. They help to spread and retain specific knowledge in teams. The use of such boards often goes hand in hand with the implementation of storyboarding or brainstorming sessions in a team to capture and spread ideas [18], [28], [39].

These examples show that creative techniques create knowledge with the help of creative exchange among team members. The use of creative techniques can encounter two common RE problems. These techniques might help if the customers are *not able to articulate* their wishes due the customer's *lack of knowledge* about what she/he wants and thus can help in case of *incomplete aggregation*.

To counteract the problems of *inability to articulate* the needs and *lack of knowledge*, each identified creative technique can be used. Storytelling as well as boards and thus also storyboarding and brainstorming sessions help to understand and internalize especially *tacit knowledge* so that customers can easily retain knowledge and minimize lacking of the same [17], [30], [39].

The *incomplete aggregation* of requirements can be prevented by the implementation of storyboarding and brainstorming sessions with the use of boards or without.

Storyboarding and brainstorming help to create, submit and tender new ideas so that new needs and requirements may come to customers' minds [39].

5 Discussion

Considering previous studies for KM in in the field of RE, software projects prove to be challenging for developers as cross-functional stakeholders, especially in distributed projects, need to specify their requirements regardless of cultural, time zone or organizational barriers [42]. Consequently, a special need for effective KM practices and methods arises.

Many RE techniques are similar to the ones of knowledge acquisition. Considering previous research, Byrd et al. [43] discovered 19 elicitation techniques that are used during knowledge acquisition or during RE. Although those results are helpful in this context, our approach significantly differs: (1) We cope with KM techniques in general. (2) Our study is problem-oriented and does not only focus on techniques related to selected problem domains (i.e., our study includes problems like *different project interests*). (3) We consider all phases of the knowledge spiral.

Our study defines six major problems in the RE and eight methods to counteract them. Concerning Nonaka's knowledge spiral it should be noted that all phases (except *internalization*) are all well-covered. Especially the *combination* phase is supported, as it is much easier to transfer *explicit knowledge* than *tacit knowledge*. Hence, all methods are applicable in the *combination* phase. There are also methods like *use of information sharing* or *use of creative techniques*, which support all four knowledge creation phases. However, this does not necessarily mean that these methods cover an especially high number of problems.

Only four methods are allocated to the *internalization* phase. This means that most methods do not support the learning process. Thus, it might be necessary to implement additional learning opportunities besides the here described KM methods.

Considering *socialization,* face-to-face interaction is most important as *tacit knowledge* is best transferred through personal interaction. Related disadvantages are that it is time-consuming, costly and sophisticated. Furthermore, personal interaction leads to high coordination effort. In some cases, it is even impossible due to geographically distributed teams. However, this study shows that there are other methods to support *socialization*. A cheaper, less time-consuming and easy to implement way are synchronous or asynchronous communication tools.

At least two solutions for each problem could be identified. The problem *different project interests* has by far the fewest possible methods allocated. This problem cannot be solved through simple knowledge transfer or creation. Instead, it is necessary to develop mutual trust to align the developer's and customer's goals.

The problem *incomplete aggregation* concerns the *tacit* dimension of knowledge. Nevertheless, there are five methods that cope with this problem. This is noteworthy as the transfer of *tacit knowledge* is often seen as more critical compared to the transfer of *explicit knowledge*.

Additionally, we emphasize that some approaches were mutually mentioned. Examples include training sessions and power user. External power users have conducted the training, so it might be possible that different approaches reveal their full potential only if mutually applied with other methods. Of course it is also possible that they amplify each other, for instance, to use search mechanisms to identify experts.

6 Conclusion

The first goal of this work was the identification of methods that can be applied to RE knowledge creation. Conducting a literature review, we were able to identify eight such methods. The second goal was to elaborate to which extent these methods facilitate and simplify the knowledge transfer between customers and developers to create new knowledge. Using the Nonaka knowledge spiral it was discovered that any method could help with at least two common RE problems (cf. section 5). In particular, face-to-face interactions and use of information sharing seem to take a special role as they could help solving five problems. Consequently, it seems likely that the identified methods are relevant for practice and that their application is useful during RE.

Although it is not always obvious which problems apply to specific projects, these methods provide an adequate first approach to reduce the risk of potential problems, thus making project failure less likely. To conclude, there are various approaches or methods of KM that are of value for the RE and should be applied in this context to encounter the existing problems.

The results of our work provide a foundation for new research in this area. First, the transferability of the methods to the context of RE has to be verified with the help of empirical validation. Second, we cannot exclude that other problems exist which the identified methods do not mitigate. Furthermore, not all the problems that might arise from the application of these methods were considered. It would be imaginable, for example, that during information sharing, team members do not want to publish their information in a centralized system because they are afraid of losing their information superiority.

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