BAR - Brazilian Administration Review
ISSN: 1807-7692
ANPAD - Associação Nacional de Pós-Graduação e Pesquisa em Administração

Francisco, Rosemary; Klein, Amarolinda da Costa Zanela
Understanding Collaborative Problem-Solving on the Move: A Design Science Research Journey
BAR - Brazilian Administration Review, vol. 17, no. 1, e180145, 2020, January-March
ANPAD - Associação Nacional de Pós-Graduação e Pesquisa em Administração

DOI: 10.1590/1807-7692bar2020180145

Available in: http://www.redalyc.org/articulo.oa?id=84163124004

https://bar.anpad.org.br

BAR – Brazilian Administration Review
Vol. 17, No. 1, Art. 4, e180145, 2020
http://dx.doi.org/10.1590/1807-7692bar2020180145

Special Issue on Design Science in Organizations

Research Article

Understanding Collaborative Problem-Solving on the Move: A Design Science Research Journey

Rosemary Francisco[1]
Amarolinda da Costa Zanela Klein[1]

[1]Universidade do Vale do Rio dos Sinos, São Leopoldo, RS, Brazil

Received 15 April 2019. This paper was with the authors for two revisions. Accepted 11 December 2019. First published online 16 March 2020.
Guest editors: Aline Dresch, Daniel Pacheco Lacerda, Paulo Augusto Cauchick-Miguel, Joan van Aken, and Raymond Opdenakker
Editor-in-chief: Carlo Gabriel Porto Bellini
Editorial assistant: Luciane Kato Kiwara

Abstract

The emergence of globally distributed teams and the evolution of mobile technologies have increased the number of mobile knowledge workers (MKW). MKW are professionals who frequently work on the move, far from a fixed workplace, performing knowledge-intensive activities. MKW often work alone, which leads them to face constant challenges in their work practices and difficulties to get timely knowledge to solve their problems alone. Still, little is known about how the collaborative problem-solving is carried out in the MKW's context. To address this gap, we adopted the Design Science Research (DSR) as a research method, and we applied activity theory (AT) and expansive learning as theoretical foundations to understand the MKW's context. We created an artifact — a method implemented via a mobile app — to support collaborative problem-solving processes on the move, which allowed us to understand better how these processes occur, contributing not only to problems resolutions but also to organizational learning.

Keywords: mobile knowledge workers; collaborative problem-solving; activity theory; expansive learning; design science research.

Introduction

The work output of knowledge workers is mainly intangible, analytic, creative, and digital, which increasingly affords them to go mobile (Jarrahi, Nelson, & Thomson, 2017). To be mobile, Knowledge Workers (MKW) tend to use mobile ICT to support their work and to get access to people and information (Karanasios & Allen, 2014). This way of performing their work practices anytime, anywhere, allows them to work where the results are better achieved (Harmer & Pauleen, 2012).

Despite the potential advantages of this flexible form of work, the context of MKW also brings them challenges. Previous literature already indicated that one of the main challenges is the MKW's relationship with their colleagues, affecting not only the related learning and collaborative processes, but also their participation in organizational activities in general (Koroma, Hyrkkänen, & Vartiainen, 2014). Working alone restricts the MKW's opportunities to form and keep up interpersonal relationships (Kietzmann et al., 2013), increases their lack of support, and also generates the feeling of being invisible, or not included, in the parent organization (Koroma et al., 2014). Working on the move can negatively affect organizational inclusion and the sense of belonging to a work team (Chen & Nath, 2008).

Thus, participation in collaborative problem-solving activities and learning at work in the context of MKW is complex (Muukkonen, Hakkarinen, Li, & Vartiainen, 2014), because working at distance from the primary workplace restricts social relationships (Jarrahi & Thomson, 2017). Geographical proximity facilitates knowledge sharing because it enables colleagues to create social relationships, increasing trust and reducing the social costs of knowledge sharing (i.e., being negatively evaluated by colleagues or losing power) (Christensen & Pedersen, 2018). Furthermore, the constantly evolving mobile technologies and emerging standards generate additional challenges, uncertain situations, and constant changes in mobile work practices (Stieglitz, Lattemann, & Brockmann, 2015).

Despite the relevance of these issues for practice, there is still a lack of academic studies that contribute to the understanding of practices related to collaborative problem-solving and learning in the context of MKW (Jarrahi & Thomson, 2017). Perhaps, one reason is that studying mobile workers is not a trivial task because the context of mobile work is related to social and environmental factors, thus conventional and widely used research methods need to be adapted (Palomäki, Hakkarainen, Vartiainen, & Heiskala, 2014).

Consequently, our work addresses this knowledge gap with the following research question: how collaborative problem-solving processes are carried out in the mobile knowledge workers' context? We are also interested in understanding how these collaborative problem-solving processes can be supported. For that reason, we applied the Design Science Research (DSR) method to better understand the research problem (Baskerville, Baiyere, Gregor, Hevner, & Rossi, 2018). The artifact created and tested in the DSR was a method, implemented via a mobile app, to support collaborative problem-solving processes on the move. We used activity theory (Engeström, 1987)

and expansive learning (Engeström & Sannino, 2010) as theoretical foundations to address the research question and to design the artifact.

We chose DSR because it can help to solve wicked problems, when solving one problem leads to another problem (Hevner, March, Park, & Ram, 2004). Besides, since to study MKW is not a trivial task, we considered that, through a DSR project, new knowledge could be derived from kernel theories (Kuechler & Vaishnavi, 2008). In addition, in our best knowledge, activity theory (AT) and expansive learning have not been used to understand how collaborative problem-solving are carried out in the MKW's context. Thus, through DSR, we applied these kernel theories from the Social Sciences to the development of an artifact and its evaluation in the MKW's real settings. The adopted approach is relevant because MKW are increasingly becoming distributed in time and space and there is a need to understand their participation in collaborative and learning activities in this context (Jarrahi et al., 2017; Kietzmann et al., 2013; Nelson, Jarrahi, & Thomson, 2017).

In the following section, we review the literature regarding the context of mobile work. We then present and discuss our theoretical foundations on collaborative problem-solving processes. The research method is explained, followed by a description of the process used to build the artifact and the results of the artifact evaluation. A discussion and concluding remarks make up the remainder of the article.

The Context of Mobile Work and Its Challenges

According to Sørensen (2011), mobile work is the most complex kind of work because the workers are mobile in both locational and interactional sense (Kakihara & Sørensen, 2002). MKW need to move to different places and perform their work practices while visiting, traveling, or commuting, frequently using mobile ICT to support their work and to interact with others (Cohen, 2010; Kakihara & Sørensen, 2002; Mäkinen, 2012). Mobile work involves the idea that the best place to work is where the work is performed in the best way (Cohen, 2010; Vartiainen et al., 2007).

Previous studies have described characteristics of the MKW's context. These workers perform knowledge-intensive work, enjoy a relative degree of autonomy, and have flexible working arrangements (Cavazotte, Lemos, & Villadsen, 2014). Moreover, they are dependent on information to execute their activities (Kietzmann et al., 2013). Their tasks are rarely repetitive and require a variety of abilities and resources to be accomplished (Cavazotte et al., 2014; Harmer & Pauleen, 2012; Kietzmann et al., 2013). MKW tend to use mobile ICT to have easy access to people and information (Cavazotte et al., 2014; Chen, 2015; Dal Fiore, Mokhtarian, Salomon, & Singer, 2014; Karanasios & Allen, 2014; Kietzmann et al., 2013). MKW often have high levels of spatial and temporal mobility, so they tend to work in various locations as well as different time zones (Jarrahi & Thomson, 2017). Cohen (2010) also mentions that any non-work spaces (such as airports or coffee shops) can be used as workspaces with some support and resources, such as mobile ICT, used by MKW.

As indicated by Vartiainen et al. (2007), knowledge work often requires collaboration because it can be complex to be performed alone. Hence, virtual meetings and conference calls are often used by MKW due to their difficulties to meet others face-to-face (Vartiainen, 2008). However, many times, it is not possible to meet synchronously in a virtual space, due to some restriction related to location, time, or technological infrastructure. Thus, their collaboration is often maintained by telephone and messaging tools (Nelson et al., 2017; Vartiainen, 2008).

To be ready to work anytime, anywhere, and to collaborate or help their co-workers and customers, a set of resources (such as laptops, smartphones, and tablets) are necessary to allow MKW to create a sort of temporary workspace (Dal Fiore et al., 2014; Jarrahi & Thomson, 2017; Vartiainen et al., 2007). Nevertheless, performing work activities across several devices and applications poses challenges for the MKW. Information and activities may become fragmented, and MKW have to continually identify new infrastructures and face the lack of transparency, interoperability, and control over the resources needed (Jarrahi & Thomson, 2017).

Mobile working arrangements present an extra layer of uncertainty and complexity, complicating the way by which artifact ecologies are constructed by individuals and employed to support their mobile knowledge work, requiring significant physical effort and planning for technological use (Jarrahi et al., 2017). According to Jarrahi, Nelson and Thomson (2017), artifact ecologies are the ways by which users, as individuals or collectives, interact with and use multiple technologies, applications, and devices, for different purposes; the composition of the artifact ecology depends on emergent needs.

In sum, the context of MKW brings challenges regarding work, collaboration, and learning, both in the individual and in the organizational dimensions. These challenges can affect the work activities performed by these workers, leading to the need for supporting their participation in collaborative problem-solving activities.

Collaborative Problem-Solving: Related Theories

Collaborative problem-solving refers to a situation where the worker is engaged with coworkers in knowledge creation and knowledge sharing to solve work-related problems and achieve the outcome of their work activity (Engeström, 2016). However, the problems that occur in the context of mobile knowledge work are often complicated, ill-defined, and unstructured, comprising activities with several workable solutions, depending on the context (Karanasios et al., 2013), challenging the way collaborative problem-solving can be performed.

In our study, we identified three main theoretical approaches related to collaborative problem-solving and knowledge creation and sharing in the organizational context: the organizational knowledge creation theory (Nonaka & Takeuchi, 1995), the situated learning perspective (Lave & Wenger, 1991), and the activity theory (Engeström, 1987; Leontev, 1978; Vygotsky, 1978). These approaches are briefly presented in the following sections.

Organizational knowledge creation theory

The organizational knowledge creation theory is a theoretical approach that focuses on the creation of knowledge in organizations (Nonaka & Takeuchi, 1995). The knowledge creation is based on three elements: (a) *Ba*, the shared context for knowledge creation; (b) the SECI process or the knowledge spiral — Socialization, Externalization, Combination, and Internalization; and (c) the knowledge assets (existing knowledge of individuals and organization). To create knowledge, the *ba* — the shared space of interaction — needs to be established, and the knowledge assets can be available, such as individual knowledge to be shared. Then, the process of knowledge creation is performed through the knowledge spiral that consists of four types of knowledge conversion (SECI process): from tacit knowledge to tacit knowledge (socialization); from tacit to explicit knowledge (externalization); from explicit to explicit knowledge (combination); and from explicit to tacit knowledge (internalization). This theoretical approach applies the participation metaphor of learning (Paavola & Hakkarainen, 2005): the knowledge already exists in the context and is acquired by the individuals through participation in the social context.

Situated learning theory

This approach is based on a social perspective and is usually used to understand the processes of organizational learning. According to Lave and Wenger (1991), people learn through participation (practices), in addition to observation and interaction with members of their social group (communities of practice). The community of practice (CoP) can be defined as a group of people who share a concern or a passion for something they practice, and regularly interact with each other to learn how to do it better (Lave & Wenger, 1991). Learning in this approach emphasizes the acquisition of knowledge as a result of social interactions and practical work sessions, where knowledge can be applied (Handley, Clark, Fincham, & Sturdy, 2007). Learning then occurs in the domain and context in which the community and its participants are situated, being inseparable from social practice (Lave & Wenger, 1991). This theoretical approach also applies the participation metaphor of learning (Paavola & Hakkarainen, 2005). Consequently, the knowledge already exists in the CoPs and can be acquired by their participants.

Activity theory and expansive learning

According to Engeström (1987), *activity* is a complex form of relationship between people and their social context and involves collective and cooperative action. Although each particular activity is distinct and dependent on its context, nevertheless all the activities have the same structure: an activity system. The elements of an activity system are the Subject, Object, Instruments (Tools and Signs), Community, Division of Labor, and Rules. These elements and the relationship between them, according to AT, are defined in Appendix B. These elements are strongly interrelated; they exist only in association with each other (Engeström, 1987).

The AT model proposed by Engeström (1987) suggests that learning is based on the expansive and qualitative changes in the human participatory activities, and this can be directly connected

to problem-solving processes. Here, expansive refers to the outcomes of participation in collaborative problem-solving activities. The sum of the individual knowledge contributes to the creation of new knowledge, going beyond the capabilities and knowledge of those individuals who took part in the collaborative problem-solving activities. Expansive learning is a type of learning in which participants, through collective zones of proximal development (ZPD), which are zones where individuals who are learning meet individuals who can help them, provoke transformations and development in their activity systems (Engeström & Sannino, 2010).

Expansive learning occurs when the isolated individual interacts with his community to solve contradictions that permeate the activity. Contradictions refer to work-related problems, such as dilemmas and conflicts in the activity (Engeström & Sannino, 2011). Contradictions are a source of potential transformation and development when combined with the participation in collaborative problem-solving. When the contradictions are solved collaboratively, based on a sense-making process, people can create a new motive or object for the collective activity, with a new principle of operation or organization (Engeström & Sannino, 2010).

Expansive learning occurs in a learning cycle composed of learning actions (see Figure 1). The typical sequence of these learning actions is described as follows (Engeström, Rantavuori, & Kerosuo, 2013): (1) the first is questioning, criticizing, or rejecting some aspects of the accepted practice and existing wisdom; (2) the second is analyzing the situation — analysis involves mental, discursive, or practical transformation of the situation in order to find out causes or explanatory mechanisms; (3) the third is modeling the newly found explanatory relationship in some publicly observable and transmittable medium; (4) the fourth is examining and testing the model, experimenting with it in order to fully grasp its dynamics, potentials, and limitations; (5) the fifth is implementing the model, such as a new work process, by means of practical applications, enrichment, and conceptual extensions; (6) the sixth is reflecting on and evaluating the process; and (7) the seventh is consolidating and generalizing the outcomes into a new stable form of practice.

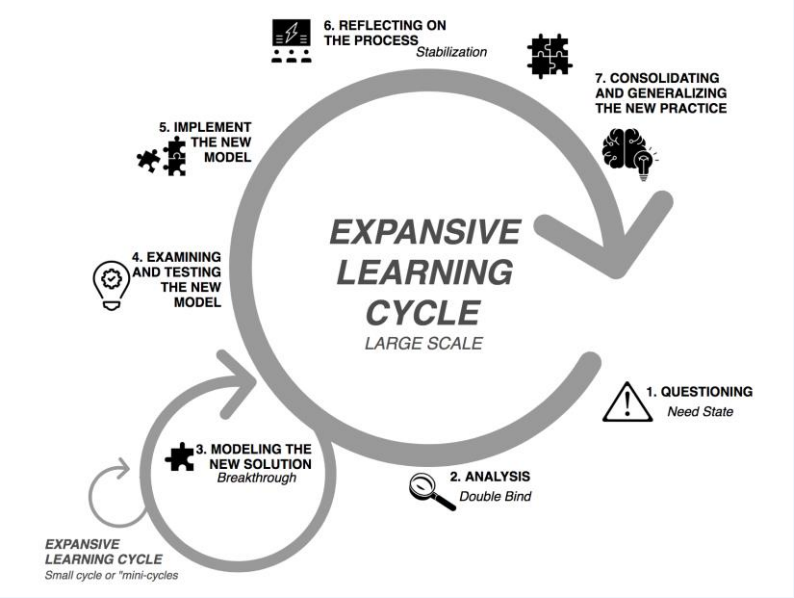


Figure 1. Large and small cycles of expansive learning
Source: Adapted from Engeström, Y., Miettinen, R., & Punamäki, R.-L. (1999). *Perspectives on activity theory* (p. 384). New York, NY: Cambridge University Press, and Engeström, Y. (2016). *Studies in expansive learning: Learning what is not yet there* (p. 54). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781316225363

A large-scale cycle of expansive learning demonstrates transformations in activity systems, often spanning a period of two or three years (Engeström, Miettinen, & Punamäki, 1999). However, a large-scale cycle usually involves numerous smaller or mini-cycles of participatory learning actions (Engeström, 2016). A smaller cycle may take place within a few days or even hours of intensive collaborative analysis and problem-solving. For instance, when the third learning action is performed (see Figure 1), smaller cycles can be carried out. However, if the smaller cycles remain as isolated events, a larger expansive cycle may not emerge (Engeström et al., 1999).

Expansive learning implies, for those individuals involved in a participatory activity, to discuss the problems, contradictions, and challenges they face, and to identify possible solutions, generating new knowledge and new ways of working. By participating in collaborative problem-solving processes, resolving contradictions and modifying work practices, knowledge can be created and shared. Hence, differently from the two other theoretical approaches previously presented, this approach adopts the knowledge-creation metaphor of learning (Paavola & Hakkarainen, 2005). Thus, there is no pre-existing knowledge, and the individuals need to create it to solve their problem situations. Table 1 presents a synthesis of the three theoretical approaches studied.

Table 1

Main characteristics of the theoretical approaches

Theoretical approach	Organizational knowledge creation theory	Situated learning	Activity theory and expansive learning
Definition	Organization's capacity to foster knowledge creation and knowledge sharing through the SECI process	Learning is situated in a context and needs the practices and social interactions among the members of a community	Learning occurs when the contradictions aroused are analyzed and solved by the participants through the creation of new knowledge
Main concepts	Tacit and explicit knowledge, sense-making	Knowledge domain, community of practice (CoP)	Activity system, zone of proximal development (ZPD), contradictions, expansive learning, learning actions
Where it occurs	*Ba* — space for knowledge sharing	Domain/situated context	Activity systems and network of activity systems
Analysis unit	SECI process	CoP	Individual and social interaction through the activity systems
Metaphor of learning	Participation	Participation	Knowledge-creation
Knowledge creation and sharing	Knowledge is created and shared based on knowledge assets and acquired via learning by doing through participation in the *ba* and SECI process	Knowledge is created and shared via learning by doing through participation in a community of practice (CoP)	Knowledge is expanded; it is something that was not there; this is made through learning actions (learning in doing) and participation of individuals from the activity systems in collaborative and problem-solving situations

Note. Source: Theoretical background.

Considering the characteristics of the three theoretical approaches, the activity theory and expansive learning were considered as the most appropriate lens to support our study, because they help us to analyze how human activities are performed through the interaction of the individuals in their social context (Engeström, 1987; Leontev, 1978; Vygotsky, 1978). Within a historical and cultural context, highlighted by this theory, it is possible to observe which dilemmas and tensions may arise from the different forms of work, working tools, and participants involved in a specific context (Engeström, 1987). As MKW have particular characteristics, motivations, and behaviors, the AT can be considered to analyze the contradictions that emerge and need to be solved to promote knowledge creation, knowledge sharing, and learning in their context (Engeström, 1987). Based on AT, it is possible to recognize who is involved in the mobile workers' activities, which artifacts can help or constrain their actions, and how they create and share knowledge, through learning actions during their work practices.

Research Method

We performed a longitudinal Design Science Research (DSR) project (Baskerville et al., 2018; Hevner & Gregor, 2013; Lacerda, Dresch, Proença, & Antunes, 2013). We followed the five design stages proposed by Kuechler and Vaishnavi (2008), as presented in Figure 2, and described next.

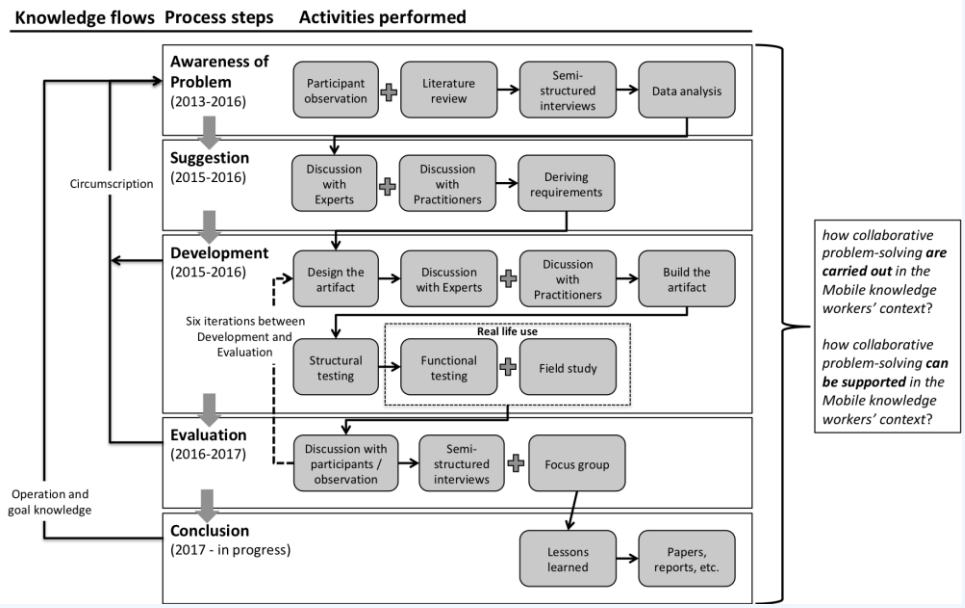


Figure 2. Design research process
Source: Adapted from Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: Anatomy of a research project (p. 493). *European Journal of Information Systems*, *17*(5), 489-504. https://doi.org/10.1057/ejis.2008.40, and Hoppen, N., Klein, A. da C. Z., & Rigoni, E. H. (2017). Sociomaterial practices: Challenges in developing a virtual business community platform in agriculture (p. 7). *Brazilian Administration Review*, *14*(2), e170006. https://doi.org/10.1590/1807-7692bar2017170006

Awareness of the problem

This phase allowed us to understand the MKW's context and their needs to solve problems collaboratively. In this phase, we conducted four research activities: (a) a participative observation, (b) a literature review, (c) semi-structured interviews with practitioners, and (d) data analysis.

The participative observation was carried out in an IT company (here denominated ITCom) that provides IT services (IT outsourcing and consulting). This organization has more than 20 years of existence in this business sector. The first author of the paper was a participative observer, working as a project manager, attempting to create a virtual environment to improve the communication and keep the organizational knowledge in a single repository. The project involved 39 participants, identified as MKW (relationship, service, and project managers) that worked most of their time in the field, attending or negotiating with clients.

Several interactions with these managers were made to identify their main characteristics and their ways of working. Mapping their processes and their responsibilities gave the researcher the chance to ask questions about their work practices and issues faced. The observations were guided by a script (Figure 3) and were made face-to-face and during virtual meetings from January 2013 until January 2015. This observation helped to understand the context of MKW and the challenges faced by them to collaborate and solve problems during mobile work.

For each manager, the following questions were asked to know their practices:

- What activities do you perform?
- What is needed to start the activity (inputs)? What is needed to end the activity (outputs/evidence)?
- When does the activity need to be performed (deadline)?
- Who provides the inputs (provider)? Who receives the outputs (customer)?
- What are the related activities?
- What are the main resources necessary to perform the activity? What are the main challenges faced to perform the activity?

Figure 3. Script of the participative observation data gathering
Source: Research instruments.

Also, to better understand the research problem, a literature review was performed. The literature review was considered to define the guidelines (see Appendix A) for semi-structured interviews performed with 31 MKW (9 of them had already taken part in the participant observation). Table 2 shows the distribution of the interviewees. The interviews were conducted remotely or in-person, at a location chosen by the participants, and lasted between 30 minutes and 1 hour and 40 minutes, and all of them were recorded and transcribed for analysis. Interviewees expressed a preference for undertaking the interviews using videoconference, audio conference, and instant messaging applications, such as Skype, WhatsApp, Google Hangouts, Appear.in, and WebEx. The mentioned tools had the advantage of being less obtrusive in the work of respondents (Cavana, Sekaran, & Delahaye, 2001) since they already relied heavily on them in their day-to-day operations. These tools also allowed to reach the interviewees wherever they were and to provide a good interview ambiance (Opdenakker, 2006). The disadvantage of this form of communication compared to face-to-face interviews is that in face-to-face interviews, there is no time delay between question and answer; the interviewer and interviewee can directly react on what the other says or does, and the interviewee can be more spontaneous (Opdenakker, 2006).

Table 2

Profile of the 31 interviewees

Position	IT relationship manager	4
	IT project/services/systems manager	6
	Business consultant	8
	Account executive	5
	CMO—chief marketing officer	1
	Lecturer	5
	Lawyer	2
Gender	Male	25
	Female	6

Continues

Table 2 (continued)

Age	20-30	7
	30-40	19
	40-50	3
	Over 50	2
Type of mobility	Alternating between two fixed locations	14
	Working at three or more places and continually moving	17
Type of interview	Face to face (coffee shop, company site, home)	3
	Online (Skype, Google Hangouts, WhatsApp, Appear.in, WebEx)	28

Note. Source: Research data

Participative observation and interviews produce a large amount of data, which introduces the challenge of how to manage and analyze the data systematically (Becker, 1958). To organize the many files in a single database, we used NVivo. We analyzed the data collected via the participant observation and the interviews by coding the data into categories and subcategories (Saldaña, 2009) related to the key concepts of AT (Engeström, 1987). The elements of the activity system (subject, instruments, object, community, rules, and division of labor) were considered as high-level categories to codify the data. We also identified and categorized the tensions and challenges that can lead to contradictions (Engeström, 1987). The concept of ZPD (zone of proximal development) was considered as a category to code episodes related to this concept. These episodes involved interactions observed or commented in the data when a novice or less experienced MKW was helped by more experienced MKW, especially in problem-solving situations. The steps of the expansive learning cycle (Engeström et al., 2013) were also considered to categorize the data about episodes involving problem-solving and knowledge creation and sharing. We present examples of the categories used in the content analysis in Appendix B.

Suggestion

In this phase, we created the first suggestion of the artifact, by defining the artifact requirements. The requirements were defined considering the data collected from the field and the literature. From the field, the participative observations and the interviews with practitioners (MKW) were fundamental to identify the artifact requirements, considering their practices and challenges faced to collaborate in problem-solving activities on the move.

From the literature, the theoretical foundations have also supported the definition of the artifact requirements, because the research theoretical background indicates the importance of collaboration and social interaction to create and share knowledge during problem-solving situations, and indicate the elements of the human activities that need to be taken into consideration in these processes. The combination of both practical and theoretical references to define the artifact requirements is aligned with the research rigor guidelines in DSR proposed by Hevner, March, Park and Ram (2004). The requirements of the artifact will be demonstrated later on the text, in Table 6. The artifact designed is a method to support collaborative problem-

solving on the move, implemented via a mobile app to be used by MKW in real work settings, as will be described later.

Development and evaluation

Based on the artifact requirements derived in the suggestion phase, the development phase started. This phase involved the design of the artifact and the development of a prototype that allowed its evaluations. The first evaluation was analytical (Hevner, March, Park, & Ram, 2004). A static analysis and also an architecture analysis of the mobile app created were carried out to identify the fit of the artifact into the technical IS architecture. We presented the first version of the method and the prototype of the mobile app to a Research Group on May 19, 2016. The presentation lasted 1 hour and 30 minutes: 30 minutes for presentation and 1 hour for discussion about the method and its instantiation (mobile app). Six participants attended the presentation: the professor and researcher coordinator of the group, one Ph.D. who is also a commercial director in an IT company, and four Ph.D. students who also have IS experience. They made comments and suggestions to improve the artifact.

We also conducted discussions and demonstrations of the artifact to other experts and practitioners. To conduct these activities, a project website was created to explain the research and to invite people to participate. Also, a total of 15 meetings/presentations were made: (a) 4 meetings with one CTO of an enterprise mobility company who had interest in the research project, (b) 2 presentations to entrepreneurship specialists and practitioners during the participation in an entrepreneurship competition, and (c) 9 meetings with professionals and managers of mobile workers in different types of organizational businesses (IT services, business, education, and industry). After these activities, the artifact was built, as will be described later in this paper.

Since the artifact was presented on the website of the project and communicated via the social networks of the researchers involved, 37 MKW requested access to the mobile app. However, only 21 used the app with a workgroup, which was a requirement to conduct collaborative problem-solving activities. The other 16 people manifested their interest, requested the access to the mobile app, accessed the app, and gave feedback about it, but they have not used it as intended (with a community). Therefore, 21 users from two sectors — education and business, divided into four cases (see Table 3) — took part in the field testing, which occurred between September 2016 and December 2016. During this period, online observations based on the usage of the mobile app were performed.

Table 3

Distribution of the groups in the field testing of the artifact

Education segment — the two groups are from the same organization (University)	Case A (EDU_A) was a team of four lecturers and one course coordinator. The team's activity was to coordinate, help, and support students in learning Java Programming in an e-learning undergraduate degree program.	5
	Case B (EDU_B) was a team of two lecturers. The team's activity was to coordinate, help, and support students in the learning of Costs and Budget for Decision Making in an e-learning undergraduate degree program.	2
Business segment	Case C (ITCON) was a team of four IT and business consultants from an IT company. The team's activity involves "thinking clients' processes" and supporting clients' processes needs. They need to understand the processes from their clients considering their business objectives and identifying possible process improvements.	4
	Case D (ITPRO) was a team of IT professionals. Each professional works in different companies, but they have similar attributions. They support their client's processes needs. They are also part of a strong network of contacts, such as strong ties (Granovetter, 1973). The primary objective of this group was to use the artifact to share common issues and problems to collaborate in their solution and, consequently, learn.	10
	TOTAL OF PARTICIPANTS	**21**

Note. Source: Research data.

The artifact was evaluated along the entire design process, and three types of evaluation were carried out (Hevner et al., 2004). First, a structural testing on the instantiation of the artifact (the mobile app developed) was performed. The structural testing was made based on the guidelines recommended by the mobile app stores: Apple Store and Google Play. To deploy mobile apps to these stores, it is necessary to follow a set of rigorous practices for mobile app development. Then, the success of the app deployment in these stores helped to validate the technical structure of the artifact.

We also carried out observational evaluations (Hevner et al., 2004) of the artifact in use in four cases of real work use (already presented in Table 3). These observations were performed inside the app created, following the logs and activities of the users, observing the way they applied the functionalities of the artifact to create and share knowledge through collaborative problem-solving on the move. All the data inserted by them inside the app was registered and analyzed, including statistics of use and the registers made by them.

Final evaluation

When the field testing finished, semi-structured individual interviews (using a script composed of 13 open research questions) and two focus groups with 20 out of the 21 participants in the case studies (see Table 3) were conducted to understand how well the artifact addressed the problem outlined. The analysis of all the evaluation data (from the observations inside the app, the registers made inside it by users, and the data collected in the focus groups and in the interviews of evaluation) was also done using the NVivo software, in which the data was coded into categories and subcategories (Saldaña, 2009) related to the key concepts of AT (Engeström, 1987), the concept of ZPD (zone of proximal development), and the steps of the expansive learning cycle (Engeström et al., 2013).

Conclusion

We conducted the lessons learned phase through the analysis of the evaluation data. In this last phase of DSR, the goal is to communicate to researchers and professionals the problem studied, the artifact provided, and the knowledge generated (Baskerville et al., 2018). It has been published in a set of publications such as in this paper.

Results

In this section, we first present the data collected that allowed us to understand the problem. After, we present the details of the artifact created to help to solve this problem, followed by the results of its evaluation.

MKW's challenges and needs for collaboration and problem-solving on the move

As noted in the participative observation in the ITCom, and also in the literature review (Harmer & Pauleen, 2012), it is common that the MKW themselves are the main responsible for their knowledge improvement. All the participants expressed concerns about their knowledge and skills, and have specializations or MBAs finished or in progress in the period of the data collection. They reinforced the need for learning and a better understanding of how to perform their work activities. As mentioned by Interviewee 10: "For instance, when I was developing a software quality system, I chose to take a particular course to understand the quality, not only understand the process but to understand the concepts and all the related things." Besides, they also mentioned that taking a formal education, such as an MBA, helps them to learn and discuss with others. "The greatest thing about doing an MBA is to exchange ideas with colleagues" (Interviewee 18). Therefore, MKW need to learn always to be prepared to perform their work activities, and it is better when it happens collaboratively.

To support their knowledge needs, we also observed that MKW often tend to use the Internet to explore a subject first, and after they use other resources such as books, materials from their formal education, mobile apps such as BBC News, and their community. Their community is not only composed of their workmates but also people from their social network:

> "I'll give you a very classic example when I use my social network, for instance, when I need to define the sales price because I'm competing with other companies ..., I have to study these companies, see if I can get their sales price elsewhere, and then I have to call three or four people who have already worked there to help me with this information." (Interviewee 22).

In the participative observation, it was commonplace to witness the commitment of these workers with their community in practices of knowledge sharing. In these collaborative problem-solving situations, the more skilled workers in the situation help the less skilled in achieving their task goals. This situation represents one of the expansive learning concepts, the zone of proximal

development (ZPD), where individuals who are learning meet individuals who can help them (Engeström, 1987).

Regarding the situations addressed in the collaborative problem-solving cases, it was observed in the literature and in the participative observation that the main challenges faced by MKW include the technology infrastructure available to support the mobile work, the need of an accurate information management, more flexible management models, dealing with unpredicted situations in several workspaces, carrying and organizing different devices and materials to work, organizing work practices (such as coordination among the mobile and fixed workers), and promoting relationships (Kietzmann et al., 2013; Koroma et al., 2014; Mäkinen, 2012). MKW may also possess higher levels of flexibility, but not have the same access to organizational support as can be found in traditional office arrangements (Nelson et al., 2017). Table 4 summarizes the main challenges identified in collaborative problem-solving situations on the move.

Table 4

Challenges faced by MKW in collaborative problem-solving on the move

Type	Challenges addressed
Technology infrastructure	• Security of devices and data • Working with their own devices • Responsibility for their technical skills • Infrastructure availability in the client organizations and temporary workplaces • Restrictions of mobile devices and equipment (small screens, lack of battery, etc.)
Information management	• Barriers to access and manage information on the move • Versioning of documents • Variety of sources necessary to get information
Management models	• Traditional management and bureaucratic models of face-to-face supervision • Lack of new styles of management for mobile work • The need of trust, commitment, and collaboration instead of control
Workplaces	• Distribution of working locations • High mobility due to traveling by car, bus, and airplanes • Different time zones, cultures, and languages • Unpredicted situations in scheduling commitments, timetables, and routes • Personal security when working on the move (robbery or lack of focus while driving) • Adequate physical spaces and structure when working on the move
A load of materials/devices	• Need to carry all the work materials and mobile devices • Need to have “survival strategies” for unpredicted situations
Relationships	• Asynchronous and synchronous ways of working • Diversity of people to deal with • Lack of time and physical proximity to strengthen relationships • Relative social invisibility and disconnectivity that come with working mobile and remotely • Commitment with colleagues and managers blurring the limits between time “on” and “off” • Sense of loyalty and obligation to others even after work hours

Continues

Table 4 (continued)

Type	Challenges addressed
Lack of boundaries between social and work context	• Almost permanent availability of individual to the organization • Temporal accessibility (modification of the temporal boundaries of the relationship between the individual and the organization) • Geographic accessibility (interactions happening anywhere) • Information and work overload due to the removal of organizational boundaries • Lack of privacy and increase in workload (possibility of an invasion of personal space)

Note. Source: Research data (participant observation, interviews, and literature review).

An interesting point about the collaborative problem-solving situations observed is that they occur mainly through mobile ICT tools. The most used ICT tools in these situations were instant messaging apps such as WhatsApp, Microsoft Lync, or Skype. Email and phone calls were also used, but the first three ones were more used since they are easier, faster, and cheaper to use (phone calls can generate high bills) to access the person who could help the MKW. They also use social media like Facebook and LinkedIn to have easy access to people. Because many times they have infrastructure problems inside the client's site or in other places, they often use their smartphones, with 3G or 4G connection and Facebook messenger to talk to the people they need to contact. Also, when they want to contact someone who makes part of their social network, but they do not have the contact details, they use Facebook and LinkedIn to reach the person. As mentioned by the Interviewee 11, "We use Facebook a lot also to connect with people; where the guy is plugged we call him (laughs)." However, during the year of 2016, a migration of communication from Facebook and LinkedIn messenger to WhatsApp was observed. Nevertheless, according to the majority of the participants, the main disadvantage of using WhatsApp, instead of other tools, is that the messages disappear and they lose the records of the conversations.

Based on all data gathered on the first phase of DSR (problem awareness), we discovered that the MKW need to engage in actively pursuing expanding their knowledge, "learning what is not yet there" (Engeström, 2016, p. 9) to achieve their work goals. Therefore, to expand their knowledge, they carry out collaborative problem-solving activities on the move mainly through mobile ICTs. Table 5 summarizes the main mobile ICTs used by the MKW to conduct collaborative problem-solving activities with their community, and also the advantages and disadvantages of each one of these tools. The artifact developed in the suggestion phase of the DSR attempted to overcome these disadvantages.

Table 5

Mobile ICTs used to conduct collaborative problem-solving on the move

Mobile ICTs	Advantages	Disadvantages
Corporate email	Help to reach people and to collaborate to solve problems asynchronously	• MKW always receive much email, and then it is hard to be focused on the problem to be solved • When the problem is urgent, email is not the best tool to get help since the response delay is high
Corporate instant messaging apps (such as Skype for business)	Help to quickly reach people from the MKW's company and to collaborate to solve problems instantly	• It is restricted to the company infrastructure; clients and contacts from the MKW's social network do not have access to it • When MKW or their co-workers are in restricted workplaces, such as a client's company, it is not possible to use these tools
Public instant messaging apps (such as WhatsApp)	Help to quickly reach people and to collaborate to solve problems asynchronously and synchronously	• They are non-institutional/official tools • The use of these tools can cause distractions because they also involve personal contacts • The problem-solving flow is dispersed and easily lost among other discussions threads
Phone calls	Help to quickly reach people and to collaborate to solve problems synchronously	• High costs • It is not possible to be used in specific situations, such as during meetings with clients • It is not adequate to register discussions/new knowledge
Social media apps (i.e., Facebook and LinkedIn)	Help to quickly reach people and to collaborate to solve problems asynchronously and synchronously	• They are non-institutional/official tools • The use of these tools can cause distractions because they also involve personal contacts • The problem-solving flow is dispersed and easily lost among other discussions threads

Note. Source: Research data.

As observed in Table 5, all the mobile ICTs used do not appropriately help the MKW to keep the registers of the knowledge generated through collaborative problem-solving activities. The knowledge generated in these tools is often dispersed and get lost among other threads. With that, MKW frequently are circling in cycles of trial and error until they reach a solution that someone may have already achieved. The challenges faced by MKW to collaborate, to create and share knowledge on the move, as well as the flaws in the mobile ICT tools already in use by them, gave space to think and design a new artifact to better support their problem-solving processes on the move, as explained in the next section.

The artifact created: a tool for better supporting collaborative problem-solving on the move

After understanding the problem (challenges faced by MKW to solve problems collaboratively on the move) and the limitations of the tools already used by them with this purpose, we started to design the artifact of the DSR, aiming to help overcome this problem.

Based on the activity theory framework proposed by Engeström (1987), each one of the MKW may be understood as a subject of one activity system, since they perform their main activities independently (see Figure 4). Each one of the MKW has instruments that are used to transform

his work object in an outcome. Some of these instruments are related to mobile ICT tools and also personal skills, such as autonomy (Koroma et al., 2014; Mazmanian, Orlikowski, & Yates, 2013). To transform the object in an outcome, MKW need to follow the rules, interact with their community, and be aware of the division of labor established for the work in progress.

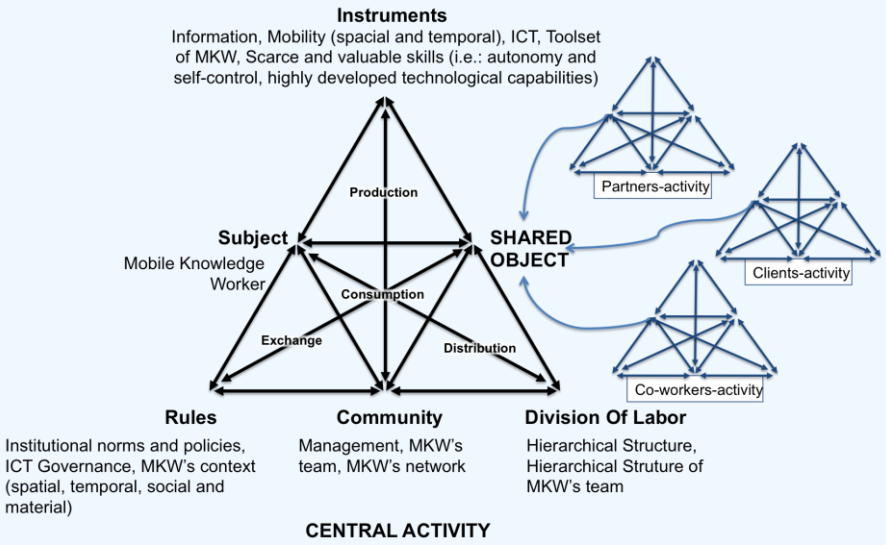


Figure 4. MKW activity system
Source: Research data and theoretical background (activity theory).

Since the MKW have a high degree of mobility, they often work alone, and many times they need to figure out by themselves what, where, when, and how their tasks need to be done (Jarrahi & Thomson, 2017). As mentioned by one IT project manager in the participative observation, "There are a lot of things to do that I have no idea how to do, and the time for me is very short, so I end up prioritizing the work with the team" (IT project manager, instant message, April 12, 2013). It reinforces the complexity of the work context and personal relations of the MKW (for example, with co-workers, clients, and partners). Based on this, we derived the first and second requirements of the artifact: (a) to allow the isolated individuals (MKW) to interact and learn with their community through problem-solving activities, and (b) to help MKW to solve their problems in their context.

Besides the high mobility of MKW, we observed in the literature and in the field that they tend to participate in collaborative practices to learn from others (Kietzmann et al., 2013; Lundin & Magnusson, 2003). This characteristic brings the idea of the ZPD – zone of proximal development (Engeström, 2016), in which participants learn with each other during problem-solving situations. Moreover, considering that MKW rarely have repetitive tasks (Yuan & Zheng, 2009), they tend to be involved in both new situations and challenges in their work activities. These challenges generate opportunities of expansive learning (as previously presented in Figure 1).

Expansive learning occurs in a learning cycle composed of learning actions and is carried out by the MKW's community involved in the work activity. This community is not only composed of their workmates but also their clients and social network. From these insights, we derived the

third requirement of the artifact: (c) to help MKW to find and know who knows what (collaborative knowledge) in their context. Since MKW make frequent use of mobile ICT (Mazmanian et al., 2013) to have easy access to people and information (Koroma et al., 2014), the fourth requirement of the artifact was derived: (d) to create opportunities for interaction anytime, anywhere (walking around in a virtual space).

Finally, as also presented in Table 5, MKW carried out collaborative problem-solving situations mainly using mobile ICTs and apps, but the knowledge generated inside these tools was often lost. Considering that keeping this knowledge is beneficial to both the MKW and their organizations, the fifth requirement of the artifact was derived: (e) to keep the knowledge created and shared in the collaborative problem-solving situations in a repository for future use. Table 6 summarizes the requirements derived from the field and the scientific literature.

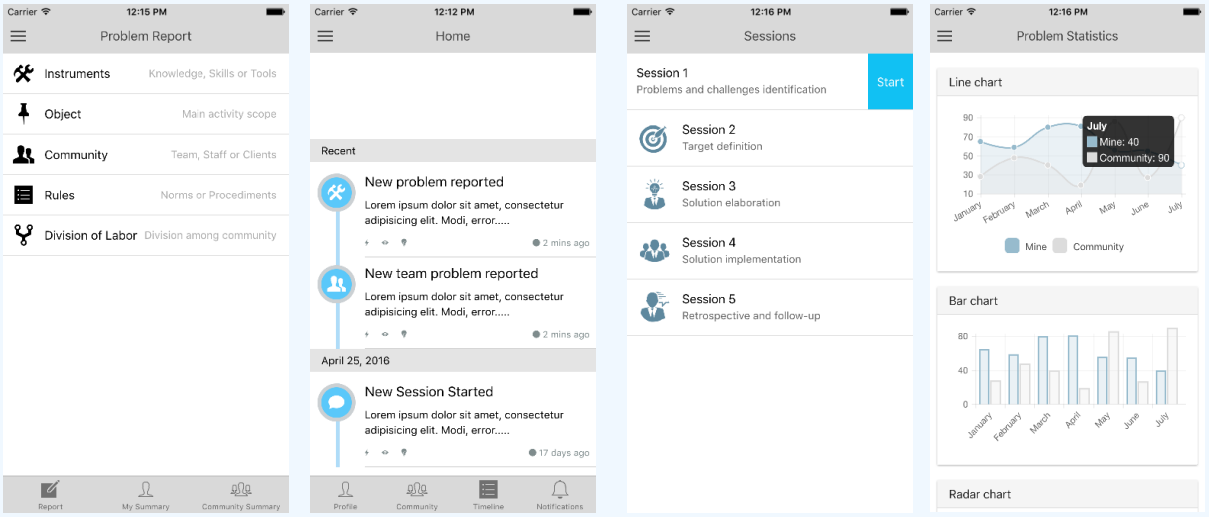
Table 6

Artifact's requirements

Requirements
(1) To allow the isolated individuals (MKW) to interact and learn with their community through problem-solving activities
(2) To help MKW to solve their problems in their context
(3) To help workers to find and know who knows what (collaborative knowledge) in their context
(4) To create opportunities for interaction anytime, anywhere (walking around in a virtual space)
(5) To keep the knowledge created and shared in the collaborative problem-solving situations in a repository for future use

Note. Source: Research data.

According to the requirements identified, we started the design of the artifact. The artifact designed is a method, instantiated through a mobile app, to support problem-solving processes on the move. Since the studies of expansive learning (Engeström, 2016) often adopt two phases, the method was also divided into the same phases used by these studies: (a) the consciousness phase and (b) the transformation phase. The primary objective of the first phase (consciousness) is to discuss the need for change in the work practices of the MKW. In our method, all the problems are self-reported by the users and presented to their community. Figure 5a illustrates the problem self-report feature on the app screen.



(a) The problem self-report screen (b) Timeline (c) Transformation sessions (d) Analysis tools

Figure 5. Main features of the artifact instantiation (mobile app screens)
Source: Research data.

The consciousness phase starts when the MKW and their community realize that there is enough evidence to work out in collaborative problem-solving. This phase is composed of five steps related to the expansive learning cycle (Engeström & Sannino, 2010). The mirror concept (a place to show the problematic issues and situations) supports the decision of the community to work collaboratively through the learning actions. This concept was implemented using a "social media timeline" feature (Figure 5b). The mirror is created based on the data collected in the workers' context, such as problem reports and logging of their contextual data and their answers to questions and debates proposed in the community. In this feature, all the problems reported by MKW in the problem self-report (Figure 5a) are presented to the community. The MKW can specify which elements of the activity system are related to the problem reported (instruments, objects, community, rules, or division of labor — see Figure 5a). Based on these features, collaborative analysis of problems through the five steps of the expansive learning cycle (Figure 5c) can be performed to overcome them (Virkkunen & Newnham, 2013).

The community of MKW can also include fixed workers, clients, or any participant that is relevant to their activities. The mobile app allows to discover if someone in the community already solved the problem reported and who is this person, and it also allows participants to comment about it and help each other in problem-solving. The mobile app also allows the register of all problem-solving processes in just one virtual, secure, and official environment. Through this memory, it is possible to know the participant's expertise (both MKW and fixed workmates) and to identify who knows what within the group. There are also tools for analyzing the data (Figure 5d) shared inside the mobile app, regarding the problems and the ideas/solutions reported, for future analysis. Table 7 illustrates one example of the collaborative problem-solving activities carried out by the ITCON case.

Table 7

One example of learning actions in the ITCON case

Example 1: Dealing with the client	
Learning step	**Example**
Problems and challenges identification (questioning)	Participant 2: How can I deal with a client that changes the requirements at any moment?
Target definition (analyzing the situation)	Participant 4: Are you validating the solution hypothesis with the client before you start developing it? Participant 2: Yes, we always validate everything before starting…
Solution elaboration (modelling and examining the model)	Participant 4: A suggestion then would be to get the client acceptance so that it does not change the requirements all the time; there will be exceptions, of course, but maybe that'll soften up a bit Participant 2: I also thought about using metrics to measure the number of related tasks done so we can show the time we are missing out on reworking the modified tasks Participant 1: You could also use the metrics to present to the client the number of changes made. This would be a way of highlighting that many changes are made after the development has started
Solution implementation (implementing the model)	The idea of using metrics is carried out by the mobile worker that had the problem (work in progress)

Note. Source: Research data.

Evaluation: how the artifact supported collaborative problem-solving in the MKW's context

We cycled between the development and the evaluation phases of the DSR process six times in order to evaluate and improve the artifact and its instantiation. It was made to keep the balance between the efforts of constructing and evaluating the evolving design artifact (Hevner, 2007), and, consequently, to provide better support to the MKW's collaborative problem-solving processes.

During the field testing, the participants of the four cases reported a total of 113 problems and 201 interactions. As illustrated in Figure 6, more than 50% of the problems reported by them were categorized as problems with their community. These results indicate that even working alone, MKW interact intensively with their community. Also, because of their characteristics, such as high mobility and autonomy, this interaction is more susceptible to problems and conflicting situations.

Another interesting result is the fact that more than 50% of the interactions were related to the occurrence of the same problem already reported by another worker ("Had the problem" interaction illustrated in Figure 7). This result indicates that it is common to have recurrent problems in the context of MKW, and, therefore, to keep the knowledge created and shared during collaborative problem-solving situations in a repository for future use is, in fact, an essential requirement to be considered.

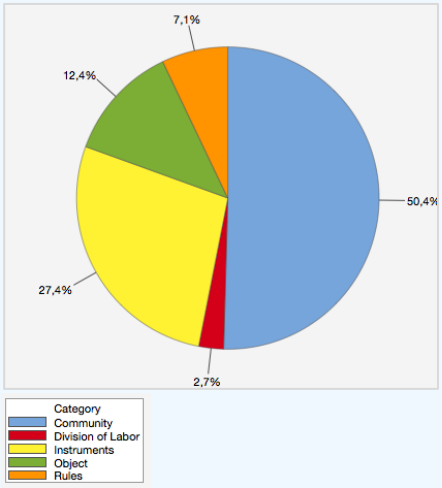


Figure 6. Total of problems reported
Source: Research data.

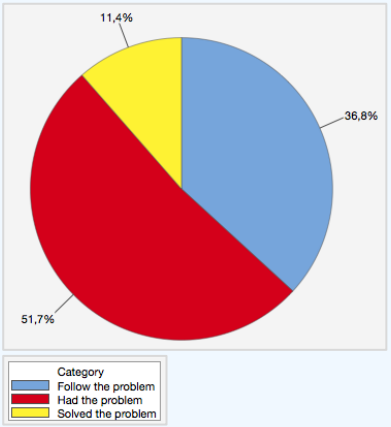


Figure 7. Total of interactions observed
Source: Research data.

As previously mentioned in the method section, the artifact evaluation was also performed through a set of meetings. We gathered positive feedback and also many contributions to improve the artifact. For instance, the use of the artifact by practitioners who wanted to help each other (not necessarily their co-workers) to develop themselves with the help of others was suggested. It is directly related to the ZPD concept, one of the key concepts in this research.

Another interesting result of these demonstrations was the idea of allowing the use of the artifact by other professionals, not only mobile workers. For instance, a contact was received from a CONFEA (Federal Council of Engineering and Agronomy) chapter in which they were interested in the artifact to perform their activities of processes improvements better:

> "I am very interested in the tool, but not only for the identification of improvements and problem-solving in the context of mobile workers. I think the tool should be very useful for other types of problem-solving related to processes in general. Would it be possible to know the tool without being in the specific context of mobile workers?" (CONFEA contact – received in response to a social media communication released).

Lastly, contacts from other entrepreneurs and companies related to BPM (business process management) and agile project management were received with an invitation to conduct partnerships:

> "I found your project very cool. We are currently launching a tool for managing agile projects. We don't have yet a mobile version to support this tool, I found your idea interesting, and I believe we could work in partnership". (Contact from an entrepreneur of a company that provides tools for agile project management).

The evaluation results indicate that the artifact developed in the DSR is useful and could help not only mobile workers but also other professionals. These results meet the main objective of the DSR method that is to make real and practical contributions.

Nevertheless, despite the positive feedback received, some obstacles were also encountered. For example, one obstacle faced was related to the use of the word "problem." It was observed some resistance to the use of this word. Many practitioners, even experts, in the evaluation phase, claimed that they did not have "problems" but "difficulties." Due to this, the word "problem" was changed by "difficulty" inside the app.

Another obstacle encountered was related to the work relations between some types of MKW and their managers. For instance, one organization that had management consultants that travel to attend clients wanted to use the artifact in a strategic project that was aimed to improve the work practices of these workers, but the company owners were resistant to make sensitive and strategic information available to the MKW (they are independent consultants). In addition, some practitioners wanted to use the artifact alone, but this was against the very goal of the artifact, that considers that learning occurs based on social interactions to stimulate collaborative problem-solving.

After these evaluations, the artifact was improved six times. Most of the improvements were made in the mobile app. First, minor changes were made in the timeline screen to help the MKW quickly know which problems already had comments from their community. Then, the notifications were evolved to allow all the participants to know where a new problem was previously reported. Afterward, there were improvements in the analytics screen, and the English version of the app was also made available. Finally, improvements in the comment fields were deployed. Other suggestions were received from the participants, for instance: (a) the possibility to use the app without an Internet access, reinforced mainly by the participants of the ITCON case, (b) the possibility to create or adapt the subcategories in the problem report, (c) the possibility to use it in a notebook or in a desktop computer — a web version, (d) the possibility to allow the MKW to create and interact with other communities in parallel — in a separated way, and (e) the possibility to register the problem and also to hear the interactions or problems registered by others through audio. The MKW stated that these features could help them when they are working on the move.

Discussion

In this section, we discuss the research results based on the guidelines proposed by Hevner et al. (2004). The first one is related to the problem relevance and the research contributions to the knowledge base. Regarding it, despite the increase in the number of MKW, the literature review disclosed a lack of studies considering the way they engage in collaborative problem-solving and learning on the move. Only two studies have been found so far (Kietzmann et al., 2013; Lundin & Magnusson, 2003) that addressed, respectively, knowledge sharing and mobile workers and collaborative learning in mobile work.

Therefore, one of our contributions to the knowledge base is to highlight this research gap and to provide empirical knowledge on the challenges faced by the MKW to solve problems collaboratively while they are working on the move. The concepts and the framework of the activity theory and expansive learning theory (Engeström, 2016) helped us to understand the context and elements in which these processes occur.

Based on the activity theory framework, it was possible to understand the application domain and to identify who is involved in the MKW's activities and what instruments help or constrain their actions, as well as to understand how they participate in collaborative problem-solving, through learning actions during their work practices. Few studies use AT as a framework to analyze the context and practices accomplished by mobile workers (Allen, Brown, Karanasios, & Norman, 2013; Karanasios & Allen, 2014), and none study so far has addressed the processes of collaborative problem-solving in the MKW's context, as suggested by Mäkinen (2012). We claim that the use of AT to understand the problem relevance in the application domain (environment) (Hevner, 2007) was effective and can help future investigations of this research subject.

The research results also reinforce the need to develop new research methods to study mobile workers while they are working on the move (Jarrahi & Thomson, 2017; Muukkonen et al., 2014; Palomäki et al., 2014). Due to the high mobility of these professionals, the application of traditional research methods such as face-to-face interviews is frequently not feasible. By using asynchronous communication tools, it is possible to reach these professionals wherever and whenever it is suitable for them.

The artifact designed was developed to facilitate the participation of the MKW in collaborative problem-solving situations on the move. As highlighted by Kietzmann et al. (2013) and Lundin and Magnusson (2003), an artifact like this can be important because professionals become more distributed in time and space and there is a need to support collaboration and learning in this new context of work.

The evaluation of the artifact had positive feedbacks. The results evidenced that, by using an artifact like this, MKW can take expansive learning actions, and they can also reach the ZPD by collaborating with other people that can help them to learn. Besides, the implementation of the mirror feature in the mobile app had the expected effect: to evidence the existence of problems and to facilitate and support the collaborative problem-solving and small cycles of expansive

learning (Engeström, 2016) towards them. One key feature of the artifact was to allow people to register the problems and also share their previous experience on them. This feature helps to keep the knowledge shared in a single and organized database that can be used in further improvements in the work processes.

In the final evaluation of the artifact, some essential improvements were pointed out by the MKW. These improvements can help to advance the support to collaborative problem-solving in the MKW's context. For instance, because MKW work with a diversity of people, the idea of allowing multiple communities in the mobile app could help them to solve problematic situations with their various communities of work. This type of results suggests that there are many possible progresses to be made on methods and applications that aim to support MKW and their processes of problem-solving, knowledge creation, and knowledge sharing on the move.

Conclusions

The main goal of this research was to address how collaborative problem-solving is carried out in MKW's context and how this process can be supported. The adoption of the DSR method allowed a deeper understanding of the research problem, the challenges faced by the MKW to solve problems on the move, and the limitations of the current tools used by them with this purpose. An artifact was designed to help overcome these challenges and limitations and succeeded in supporting MKW's participation in collaborative problem-solving activities. The activity theory framework was applied (Figure 4), helping to understand what are the main elements involved in these activities, and the expansive learning cycles were considered to design the collaborative problem-solving method implemented via the mobile app.

The research contributes to the knowledge base on mobile work, helping to understand how MKW solve problems, collaborate, and, consequently, create and share knowledge on the move. The empirical knowledge generated by this research is relevant considering that little research has been developed to understand these processes, despite the increase in the number of mobile workers and new flexible forms of work supported by mobile ICT.

This research also makes practical contributions because the artifact developed can be used not only by the MKW but also by the management of MKW, HR professionals, IT teams and back-office teams of the companies that support MKW, other professionals who use mobile ICT to work, and also software developers. The artifact can also help MKW to reflect on their participation in collaborative work practices and the challenges they face, stimulating them to look for new ways of working better, and supporting each other. Besides, since the instantiation of the artifact can store the data generated by the MKW's collaborative problem-solving activities, it is also possible to use this data for future work analysis via data science and analytical tools.

Our findings also highlight the importance of further research on this topic. The rise of MKW is related to the constant evolution of new mobile and ubiquitous ICTs such as biometric readers, wearables, voice control, near-field communications, augmented reality, etc. Therefore, new technologies and new ways of supporting collaborative problem-solving processes on the move,

building on our theoretical approach, can be considered to design new technologies for participation in collaborative problem-solving situations, for example, using augmented reality. As this study concentrates on MKW, future studies can use the framework and procedures introduced in this research in other forms of mobile work. Finally, future studies can address the large-scale cycle of expansive learning during mobile work.

This research had some limitations. First, the artifact was evaluated with a small number of MKW. Additionally, due to the limited period of field testing of the DSR artifact, it was not possible to observe complete large-scale cycles of expansive learning. Therefore, we suggest future studies to test the generalizability of our results to a broader MKW context and also other domains of work.

Acknowledgements

This work was supported by the CNPq under grant No. 425672/2016-6 – Universal Grant and No. 309268/20168 (Productivity Scholarship of Amarolinda Klein).

References

Allen, D. K., Brown, A., Karanasios, S., & Norman, A. (2013). How should technology-mediated organizational change be explained? A comparison of the contributions of critical realism and activity theory. *MIS Quarterly*, *37*(3), 835-854. https://doi.org/10.25300/misq/2013/37.3.08

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Rossi, M. (2018). Design science research contributions: Finding a balance between artifact and theory. *Journal of the Association for Information Systems*, *19*(5), 358-376. https://doi.org/10.17705/1jais.00495

Becker, H. S. (1958). Problems of inference and proof in participant observation. *American Sociological Review*, *23*(6), 652-660. https://doi.org/10.2307/2089053

Cavana, R. Y., Sekaran, U., & Delahaye, B. L. (2001). *Applied business research: Qualitative and quantitative methods*. Milton, Australia: John Wiley & Sons Inc.

Cavazotte, F., Lemos, A. H., & Villadsen, K. (2014). Corporate smart phones: Professionals' conscious engagement in escalating work connectivity. *New Technology, Work and Employment*, *29*(1), 72-87. https://doi.org/10.1111/ntwe.12022

Chen, L. (2015, March). A model of mobile work continuance of knowledge workers: Evidences from China. *Proceedings of The Third International Conference on E-Technologies and Business on the Web (EBW2015)*, ESG Management School, Paris, France.

Chen, L., & Nath, R. (2008). A socio-technical perspective of mobile work. *Information, Knowledge, Systems Management*, *7*(1-2), 41-60. Retrieved from https://content.iospress.com/articles/information-knowledge-systems-management/iks00118

Christensen, P. H., & Pedersen, T. (2018). The dual influences of proximity on knowledge sharing. *Journal of Knowledge Management*, *22*(8), 1782-1802. https://doi.org/10.1108/jkm-03-2018-0211

Cohen, R. L. (2010). Rethinking "mobile work": Boundaries of space, time and social relation in the working lives of mobile hairstylists. *Work, Employment & Society*, *24*(1), 65-84. https://doi.org/10.1177/0950017009353658

Dal Fiore, F., Mokhtarian, P. L., Salomon, I., & Singer, M. E. (2014). "Nomads at last"? A set of perspectives on how mobile technology may affect travel. *Journal of Transport Geography*, *41*, 97-106. https://doi.org/10.1016/j.jtrangeo.2014.08.014

Engeström, Y. (1987). *Learning by expanding: An activity theoretical approach to developmental research*. Helsinki, Finland: Orienta-Konsultit.

Engeström, Y. (2016). *Studies in expansive learning: Learning what is not yet there*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781316225363

Engeström, Y., Miettinen, R., & Punamäki, R.-L. (1999). *Perspectives on activity theory*. New York, NY: Cambridge University Press.

Engeström, Y., Rantavuori, J., & Kerosuo, H. (2013). Expansive learning in a library: Actions, cycles and deviations from instructional intentions. *Vocations and Learning*, *6*(1), 81-106. https://doi.org/10.1007/s12186-012-9089-6

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, *5*(1), 1-24. https://doi.org/10.1016/j.edurev.2009.12.002

Engeström, Y., & Sannino, A. (2011). Discursive manifestations of contradictions in organizational change efforts: A methodological framework. *Journal of Organizational Change Management*, *24*(3), 368-387. https://doi.org/10.1108/09534811111132758

Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology*, *78*(6), 1360-1380. https://doi.org/10.1086/225469

Handley, K., Clark, T., Fincham, R., & Sturdy, A. (2007). Researching situated learning: Participation, identity and practices in client–consultant relationships. *Management Learning*, *38*(2), 173-191. https://doi.org/10.1177/1350507607075774

Harmer, B. M., & Pauleen, D. J. (2012). Attitude, aptitude, ability and autonomy: The emergence of 'offroaders', a special class of nomadic worker. *Behaviour & Information Technology*, *31*(5), 439-451. https://doi.org/10.1080/0144929x.2010.489117

Hevner, A. R. (2007). A three cycle view of design science research. *Scandinavian Journal of Information Systems*, *19*(2), 87-92. Retrieved from https://aisel.aisnet.org/sjis/vol19/iss2/4

Hevner, A. R., & Gregor, S. (2013). Positioning and preenting design science: Types of knowledge in design science research. *MIS Quarterly*, *37*(2), 337-355. https://doi.org/10.25300/misq/2013/37.2.01

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75-105. https://doi.org/10.2307/25148625

Hoppen, N., Klein, A. da C. Z., & Rigoni, E. H. (2017). Sociomaterial practices: Challenges in developing a virtual business community platform in agriculture. *Brazilian Administration Review*, *14*(2), e170006. https://doi.org/10.1590/1807-7692bar2017170006

Jarrahi, M. H., Nelson, S. B., & Thomson, L. (2017). Personal artifact ecologies in the context of mobile knowledge workers. *Computers in Human Behavior*, *75*, 469-483. https://doi.org/10.1016/j.chb.2017.05.028

Jarrahi, M. H., & Thomson, L. (2017). The interplay between information practices and information context: The case of mobile knowledge workers. *Journal of the Association for Information Science and Technology*, *68*(5), 1073-1089. https://doi.org/10.1002/asi.23773

Kakihara, M., & Sørensen, C. (2002). Mobility: An extended perspective. *Proceedings of the Annual Hawaii International Conference on System Sciences*, Big Island, HI, USA, 35. https://doi.org/10.1109/hicss.2002.994088

Karanasios, S., & Allen, D. (2014). Mobile technology in mobile work: Contradictions and congruencies in activity systems. *European Journal of Information Systems*, *23*(5), 529-542. https://doi.org/10.1057/ejis.2014.20

Karanasios, S., Thakker, D., Lau, L., Allen, D., Dimitrova, V., & Norman, A. (2013). Making sense of digital traces: An activity theory driven ontological approach. *Journal of the American Society for Information Science and Technology*, *64*(12), 2452-2467. https://doi.org/10.1002/asi.22935

Kietzmann, J., Plangger, K., Eaton, B., Heilgenberg, K., Pitt, L., & Berthon, P. (2013). Mobility at work: A typology of mobile communities of practice and contextual ambidexterity. *Journal of Strategic Information Systems*, *22*(4), 282-297. https://doi.org/10.1016/j.jsis.2013.03.003

Koroma, J., Hyrkkänen, U., & Vartiainen, M. (2014). Looking for people, places and connections: Hindrances when working in multiple locations: A review. *New Technology, Work and Employment*, *29*(2), 139-159. https://doi.org/10.1111/ntwe.12030

Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: Anatomy of a research project. *European Journal of Information Systems*, *17*(5), 489-504. https://doi.org/10.1057/ejis.2008.40

Lacerda, D. P., Dresch, A., Proença, A., & Antunes, J. A. V., Júnior. (2013). Design science research: Método de pesquisa para a engenharia de produção. *Gestão & Produção*, *20*(4), 741-761. https://doi.org/10.1590/s0104-530x2013005000014

Lave, J., & Wenger, E. (1991). *Situated learning*. New York, NY: Cambridge University Press.

Leontev, A. N. (1978). *Activity, consciousness, and personality*. Englewood Cliffs, NJ: Prentice-Hall.

Lundin, J., & Magnusson, M. (2003). Collaborative learning in mobile work. *Journal of Computer Assisted Learning*, *19*(3), 273-283. https://doi.org/10.1046/j.0266-4909.2003.00029.x

Mäkinen, S. (2012). Mobile work and its challenges to personal and collective information management. *Information Research*, *17*(3). Retrieved from http://InformationR.net/ir/17-3/paper522.html

Mazmanian, M., Orlikowski, W. J., & Yates, J. (2013). The autonomy paradox: The implications of mobile email devices for knowledge professionals. *Organization Science*, *24*(5), 1337-1357. https://doi.org/10.1287/orsc.1120.0806

Muukkonen, H., Hakkarinen, K., Li, S., & Vartiainen, M. (2014). Tracking mobile workers' daily activities with the contextual activity sampling system. In A. Marcus (Ed.), *Design, user experience, and usability. User experience design for diverse interaction platforms and environments* (pp. 289-300). https://doi.org/10.1007/978-3-319-07626-3_27

Nelson, S. B., Jarrahi, M. H., & Thomson, L. (2017). Mobility of knowledge work and affordances of digital technologies. *International Journal of Information Management*, *37*(2), 54-62. https://doi.org/10.1016/j.ijinfomgt.2016.11.008

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company*. New York, NY: Oxford University Press.

Opdenakker, R. (2006). Advantages and disadvantages of four interview techniques in qualitative research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *7*(4), 1-13. Retrieved from http://nbn-resolving.de/urn:nbn:de:0114-fqs0604118

Paavola, S., & Hakkarainen, K. (2005). The knowledge creation metaphor - An emergent epistemological approach to learning. *Science and Education*, *14*(6), 535-557. https://doi.org/10.1007/s11191-004-5157-0

Palomäki, E., Hakkarainen, K., Vartiainen, M., & Heiskala, M. (2014). Methods to study everyday activities in a mobile work context - A literature overview. In A. Marcus (Ed.), *Design, user experience, and usability. User experience design for diverse interaction platforms and environments* (pp. 301-312). https://doi.org/10.1007/978-3-319-07626-3_28

Saldaña, J. (2009). *The coding manual for qualitative researchers*. London, UK: SAGE Publications Ltd.

Sørensen, C. (2011). *Enterprise mobility: Tiny technology with global impact on work*. London, UK: Palgrave Macmillan.

Stieglitz, S., Lattemann, C., & Brockmann, T. (2015). Mobile applications for knowledge workers and field workers. *Mobile Information Systems*, *2015*, 1-8. https://doi.org/10.1155/2015/372315

Vartiainen, M. A. (2008). Facilitating mobile and virtual work. In C. Wankel (Ed.), *21st century management, A reference handbook* (Vol. II, pp. 348-360). http://dx.doi.org/10.4135/9781412954006.n84

Vartiainen, M., Kakonen, M., Koivisto, S., Mannonen, P., Nieminen, M. P., Ruohomäki, V., & Vartola, A. (2007). *Distributed and mobile work: Places, people and technology*. Heidelberger, Germany: Springer.

Virkkunen, J., & Newnham, D. S. (2013). *The change laboratory - A tool for collaborative development of work and education*. Rotterdam, Netherlands: Sense Publishers.

Vygotsky, L. S. (1978). *Mind and society*. Cambridge, MA: Harvard University Press.

Yuan, Y., & Zheng, W. (2009). Mobile task characteristics and the needs for mobile work support: A comparison between mobile knowledge workers and field workers. *Proceedings of International Conference on Mobile Business*, Dalian, China, 8.

Author contributions

1st author: conceptualization (lead), data curation (lead), formal analysis (lead), funding acquisition (lead), investigation (lead), methodology (lead), project administration (lead), resources (lead), software (lead), supervision (lead), validation (lead), visualization (lead), writing-original draft (lead), writing-review and editing (lead).
2nd author: conceptualization (supporting), data curation (supporting), formal analysis (supporting), funding acquisition (supporting), investigation (supporting), methodology (supporting), project administration (supporting), resources (supporting), software (supporting), supervision (supporting), validation (supporting), visualization (supporting), writing-original draft (supporting), writing-review and editing (supporting).

Authors

Rosemary Francisco
Universidade do Vale do Rio dos Sinos
Av. Unisinos, 950, 93022-000, São Leopoldo, RS, Brazil
rmaryf@gmail.com
http://orcid.org/0000-0001-6723-9938

Amarolinda da Costa Zanela Klein
Universidade do Vale do Rio dos Sinos, Programa de Pós-graduação em Administração
Av. Unisinos, 950, 93022-000, São Leopoldo, RS, Brazil
amaroklein@gmail.com
http://orcid.org/0000-0001-8585-9057

APPENDIX A

Interview questions — Understanding the problem

This is an authorized adaptation of the instrument elaborated by Karanasios and Allen (2014).

About the subject

1. Age, gender, education, profession, background, and experience (How long?)
2. What is your organizational position? How long do you work in this position and company?
3. What is your employment modality? For instance, some mobile workers are small companies working for big companies.

About the activity/object/outcome

4. Can you describe, briefly, what do you do in your job?
5. Which places do you often use to perform this job? For instance, in the literature the job can be performed "on the move": from home, at client's site, in the car, in a restaurant, etc.
6. What is your main workplace? How much time do you spend outside the main workplace?
7. Could you talk, in summary, how is your daily routine?
8. What are the main problems encountered in your daily routine? How do you solve them? Social and technical issues.

About the instruments

9. Which mobile devices and applications do you often use (personal and professional)? Why do you use them? Which are yours and which are from your organization? Concrete devices and applications used.
10. Which mobile and ubiquitous technologies do you often use to perform your job?
11. Are you able to perform your activity at anywhere because you have these [mobile and ubiquitous technologies]? Why? How? Give some examples.
12. What other tools do you use to perform your job? For instance, the literature presents these instruments: ICT, mobile devices, communication tools, information tools, time zone, language, collaborative practices, etc.
13. Has your perception of your job changed since you've been using mobile and ubiquitous technologies?

About the rules

14. What conventions, norms, or procedures you need to follow to perform your job?
15. Could you talk me through a job task with and without the mobile and ubiquitous technologies? What rules and norms have changed?
16. Are there any rules or norms to follow in the places you often use to work? For instance: public workplaces, client's site, etc.

About the community

17. When do you need to interact with others to perform your activity? Why? Give some examples.
18. Do others interact with you during the daily work? Why? Give some examples.
19. Does the use of mobile and ubiquitous technologies changed your way to interact with others? Why? Give some examples.

About the division of labor

20. Has mobile technology changed the way you work with your supervisor/coordination/client? Why? Give some examples.
21. Do you think they can supervise/manage better? Or more intrusively? Why?

About knowledge creation and sharing

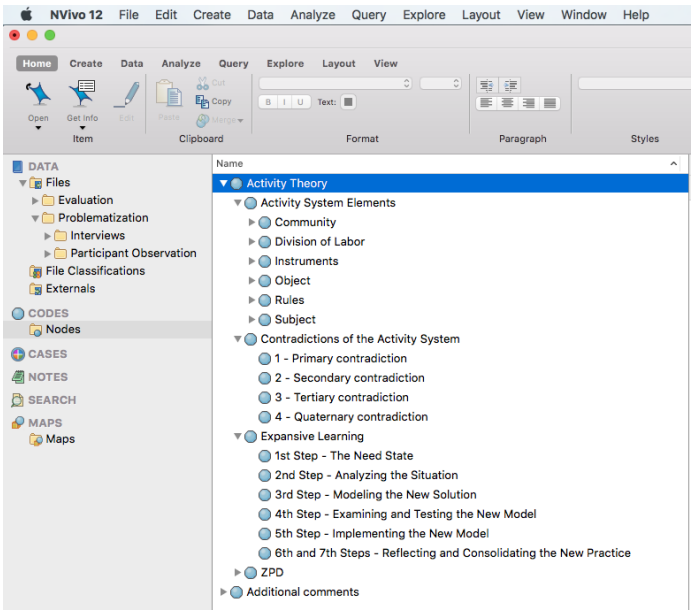
22. Where do you usually seek knowledge to solve your problems? Give some examples.
23. What do you do when you face some new situation in the work? Do you look for help in your team/network? Give some examples.
24. When you learn how to lead with this new situation, do you share with someone?
    a. Yes: Can you describe how does this happen? Which tools do you use? How often does it happen? Give some examples.
    b. No: What does make difficult to share? Why? Give some examples.
25. When you started in your company, where did you get the information to do your job? Did you have some training? Did someone help you? Give some examples. What was more effective: training or people help?

Additional comments

26. Do you have some additional comments?

APPENDIX B

Codification example

ACTIVITY SYSTEM ELEMENTS		
Category	**Definition**	**Nodes codification in NVivo**
Subject	Individual or sub-groups who perform the activity, selected from the viewpoint of analysis.	
Object	The object represents the goals of human activity and allows the individual to control his own motives and behavior during the accomplishment of the activity. The activity, thus, is directed to the satisfaction of these goals.	
Instruments (tools and signs)	There are artifacts used to mediate the relationship between the subject and his object in the activity accomplishment. The instruments can be any tools or signs that allow the subject to transform his object in an outcome.	
Community	Individuals or sub-groups who share the same object. The community is located within a socio-cultural context of those who share the same object of activity. Rules and division of labor mediate the relationship between subject and community.	
Division of labor	The division of labor refers both to the horizontal division of labor among the members of the community and to the vertical division of power and status.	
Rules	Refer to the explicit and implicit rules, norms, and conventions that restrict the actions and interactions within the activity system.	