Knowledge Mapping in a Research and Development Group
A Pilot Study

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Keywords: Knowledge Management, Knowledge Mapping, Knowledge Map.

Abstract: In Enterprise Systems, representing the flow of knowledge may indicate how participants work using their knowledge. Such representation allows the understanding of how knowledge circulates between the development team and improvement opportunities. Knowledge Management supports the management of knowledge through techniques that identify how knowledge behaves in projects. One of these techniques is Knowledge Mapping, which supports representing how participants share their knowledge, which sources of knowledge are consulted and which people it helps during a project. However, to draw up a knowledge map, we need a process for capturing and analyzing data that can extract information that reflect these aspects. This work aims at presenting a process for Knowledge Mapping to develop a map indicating what knowledge the participants used, who or what they accessed and indications of its core competencies. Additionally, this paper discusses a pilot study regarding the application of the proposed process. As a result, we generated a knowledge map for a software engineering research and development group, in which contains a set of profiles and features what the main skills that a participant uses are.

1 INTRODUCTION

The main asset of Software Companies is knowledge. Thus, it is necessary to manage this knowledge and use their experiences in development activities (Hansen and Kautz, 2004). In any industrial or academic environment, there are people who have knowledge, and it may be of interest to promote such knowledge management (Krbálek and Vacek, 2011).

Knowledge management is the process of creating, validating, representing, distributing and applying knowledge (Bhatt, 2001). Knowledge management also refers to identifying and increasing the collective knowledge in an organization to help it become more competitive (Alavi and Leidner, 2001).

The goal of these efforts is to provide members of the organization with the knowledge they need to maximize their effectiveness, thus improving the efficiency of the organization (Mitchell and Seaman, 2011). The environment or territory in the context of knowledge management is not geographical, but intellectual (Eppler, 2001), where we need techniques that seek to represent the main aspects of that environment.

One of the techniques in Knowledge Management that seeks to represent these aspects is Knowledge Mapping. Knowledge mapping is a process of surveying, assessing and linking the information, knowledge, competencies and proficiencies held by individuals and groups within an organization (Anandarajan and Akhilesh, 2012).

The result of a mapping is a Knowledge Map that shows the relationships among the procedures, concepts and skills, which provides easy and effective access to sources of knowledge (Balaid *et al.*, 2013). The main purpose and benefit of a knowledge map are to show people from within the company where to go when they need knowledge (Davenport and Prusak, 1998).

This paper presents a process of knowledge mapping that aims at representing the flow of the employees' knowledge within software organizations. We combined some approaches in order to create such process. This paper also describes the results of a pilot study in which the proposed process was applied in a Research and Development (R&D) group.

The remainder of this paper is organized as follows. Section 2 presents our theoretical reference. Section 3 presents the developed knowledge mapping process. Section 4 shows planning process

Filho, E., Viana, D., Rabelo, J. and Conte, T.
Knowledge Mapping in a Research and Development Group - A Pilot Study.
In *Proceedings of the 18th International Conference on Enterprise Information Systems (ICEIS 2016) - Volume 1*, pages 306-317
ISBN: 978-989-758-187-8

of the pilot study. Section 5 discusses the results obtained in the pilot study. Finally, Section 6 presents our conclusions and future work.

2 THEORETICAL REFERENCE

Individual knowledge is necessary for the development of knowledge within an organization (Bhatt, 2001). Knowledge within an organization is a collection of knowledge, experiences and information which people or groups employ to carry out their tasks (Vasconcelos *et al*., 2005). This section shows the theoretical reference and the main concepts for this work.

2.1 Knowledge Management

Human resources are the main assets of many companies where knowledge has to be preserved and passed from the individual to the organizational level, enabling continuous improvement and learning (Lindvall *et al*., 2003). Companies generally understand Knowledge as how information is encoded with a high proportion of human value-added, including perception, interpretation, context, experience, wisdom, and so on (Davenport and Völpel, 2001).

Davenport and Prusak (1998) made a distinction between data and information. Data is a group of distinct facts and goals related to events. Information aims at changing the way in which the receiver perceives something, exercising some impact on his/her judgment and behavior.

Nonaka and Takeuchi (1995) states that knowledge, unlike information, is about beliefs and commitment, and characterize it into two types: explicit and tacit. Explicit or codified knowledge can be articulated in formal or textual language. Tacit knowledge is the personal knowledge, incorporated to the individual experience, and that involves intangible factors (e.g. personal beliefs, perspectives and value systems).

Knowledge Management is a method that simplifies the process of sharing, distributing, creating and comprehending a company's knowledge (Bjørnson and Dingsøyr, 2008). Its goal is to solve problems regarding the identification, localization and usage of knowledge (Rus and Lindvall, 2002).

A prerequisite for the strengthening of knowledge management is a good understanding of how knowledge flows within the organization (Hansen and Kautz, 2004). The identification of the knowledge flow shows us the way on which new concepts and ideas are spread, which can be useful to facilitate changes in management initiatives (Gourova *et al*., 2012). One of the applied techniques for searching and defining organizational knowledge flow is knowledge mapping.

2.2 Knowledge Mapping

Knowledge mapping is a process, method, or tool made for analyzing knowledge in order to discover characteristics or meanings, and view knowledge in a comprehensible and transparent manner (Jafari *et al.*, 2009). The purpose of knowledge mapping is to seek a better orientation in a given domain and access knowledge from the right people at the right time (Krbálek and Vacek, 2011).

One of the advantages of knowledge mapping includes the freedom to organize without restriction, meaning that there are no limits to the number of ideas and connections that can be made (Nada *et al.*, 2009). Knowledge mapping usually takes part of Knowledge Audit processes and methodologies.

Elias *et al*. (2010) define Knowledge Audit (KA) as the identification, analysis and evaluation of the activities, processes and practices for managing the knowledge that a company already has.

Knowledge Audit is used to provide an investigation into the organization's knowledge about the health of knowledge (Elias *et al*., 2010), identifying and understanding the knowledge needs in organizational processes.

Meanwhile, by using Knowledge Mapping techniques would show a logical structure of relationships between tacit human knowledge and explicit knowledge in documents (Krbálek and Vacek, 2011). The result of knowledge mapping is a knowledge map.

2.3 Knowledge Map

Knowledge Map is a diagram that can represent words, ideas, tasks, or other items linked to and arranged in radial order around a central key word or idea (Nada *et al.*, 2009). Furthermore, it is an interactive and open representation that organizes and builds structures and procedural knowledge used in the pursuit of exploration and problem solving (Anandarajan and Akhilesh, 2012).

Knowledge maps also provide a holistic view of knowledge resources (Balaid *et al*., 2013). Eppler (2001) distinguishes five types of Knowledge Maps, shown in Table 1. The five maps can be combined to generate new mapping techniques.

Table 1: Types of Knowledge Maps (Eppler, 2001).

Name	Description
Knowledge Source Maps	These are maps that structure a population of experts from a company through search criteria, such as their knowledge domain, proximity, length of service or geographical distribution.
Knowledge Asset Maps	This type of map visually describes the storage of knowledge of a person, a group, a unit or an organization.
Knowledge Structure Maps	It is the overall architecture of a knowledge domain and shows how parts relate to each other. It assists managers in understanding and interpreting a specialized field.
Knowledge Application Maps	It shows what kind of knowledge must be applied at certain stages of the design process or in a specific business situation. It answers the question of which people are involved in an intensive knowledge process, such as auditing, consulting, research or product development.
Knowledge Development Maps	These maps can serve as development pathways or visual learning which provide a common corporate vision for organizational learning.

2.4 Related Work

There are different techniques to map organizational knowledge, and each technique can use a set of tools, approaches, objectives and specific characteristics (Jafari *et al*., 2009). In the following paragraphs, we show the main works that served as the theoretical basis for our mapping proposal.

Hansen and Krautz (2004) proposed using Rich Pictures (mechanism that uses pictograms for representation) as a technique to map the flow of organizational knowledge. The methodology consists of two large main stages: preparation phase and mapping phase.

- Preparation Phase: Based on the collected data, (s)he created an initial map of the organization.
- Mapping phase: It results in a knowledge map that describes actors and knowledge flow, as well as key features of the organization.

Hwang and Kim (2003) defined that a map is composed of two main components: diagrams that are graphical representations of components; and specifications, which are descriptions of the components. The authors also suggested creating a profile of the extracted knowledge, establishing a structure representing the characteristics of the mapped knowledge.

According to Kim and Hwang (2003), knowledge maps should achieve:

1. Formalization of all the knowledge inventories in the organization;
2. Perception of the relationship between knowledge;
3. Efficient Navigation of knowledge inventories;
4. Promotion of socialization/outsourcing of knowledge by connecting the experts' domains with knowledge explorers.

Eppler (2001) has developed five steps that must be performed to design and build a Knowledge Map. These are:

1st. Step: To identify the knowledge-intensive processes, problems or issues within the organization. The resulting map should focus on improving the intensive knowledge.

2nd. Step: To deduce the sources of knowledge, assets or relevant process elements or problems.

3rd. Step: To codify these elements in a way that it makes them more accessible to the organization.

4th. Step: To integrate this codified knowledge or documents information in a visual interface that allows the user to navigate or search for it.

5th. Step: To provide means for updating the Knowledge Map. A Knowledge Map is as good as the links it provides. If these links are outdated or obsolete, the map is useless.

The mapping techniques found in the literature show some approaches focusing on the flow of knowledge within the organization and the definition of knowledge sources. However, improved techniques may be applied to represent participants' knowledge based on knowledge flow.

Finally, Elias *et al.* (2007) proposed a methodology to identify and analyze knowledge flows in work processes. Such stages are:

1. To identify the main documents and people involved in the process;
2. To analyze the knowledge sources identified in the first step;
3. To identify how the knowledge and sources are involved in the activities performed in the process;
4. To analyze to find the problems that could be affecting knowledge flows identified.

The purpose of this paper is to integrate and improve these previous methods and generate a set of profiles of the participants in a software project team. From the data of these profiles, we can verify what is the most used knowledge by participants.

3 PROCESS OF KNOWLEDGE MAPPING IN SOFTWARE TEAMS

Our Process of Knowledge Mapping is mainly based on the work of Hansen and Kautz (2004), since their method allows enhancements or modifications. Furthermore, the work by Kim and Hwang (2003) contributes to the profiling strategy and the work by Eppler (2001) contributes to the definition of the steps to build the knowledge maps.

The main objective of the map is to find the core competencies of the participants based on their interaction with other team members and with sources of knowledge. The procedure of the Knowledge mapping consists of two phases:

- **Data Collection Phase**: The data that will compose the Knowledge Map will be collected. The collected data can come from two sources in the organization: the project or organization. Regardless of the origin, this phase will organize the data that will be employed to build a map of the structure;
- **Mapping Phase:** It is the organization of the data and the construction of the Knowledge Map. According to Table 1, the produced map is classified as a Knowledge Source Map, showing the sources of explicit (websites, books or documents) and tacit (participants) knowledge. Moreover, a profile for each participant will be produced, indicating his/her main accessed knowledge.

The moderator of the Knowledge Mapping Process can play many roles such as facilitator (during the data collection phase) or map developer (during the mapping stage).

3.1 Data Collection Phase

The purpose of the data collection phase is to extract the necessary information to create the Knowledge Map, as shown in Figure 1.

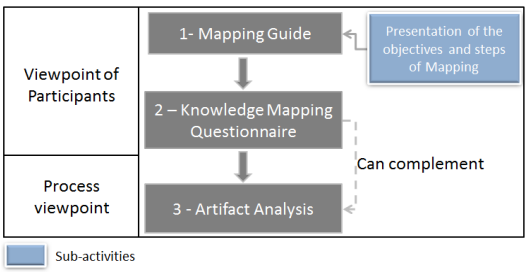

Figure 1: Activities of the data collection stage from the Knowledge Mapping process.

1. The Mapping Guide is a presentation showing the participants which activities they will do during the meeting. The purpose of the presentation is to support the facilitator of the meeting and present a practical visual guide to participants;
2. We apply the questionnaire to the participants who will create the Knowledge Map;
3. Analyzing Artifacts. The purpose of this activity is to see how organizations or group view the participants and to triangulate the facts with the questionnaire information.

We describe these activities in the following subsections.

3.1.1 Presentation of the Mapping Guide

The Mapping Guide should be presented to the participants of the meeting before the questionnaire. The structure of the presentation follows the following steps:

- Presentation of the Facilitator and his role for the group;
- Explanation of what is tacit and explicit knowledge;
- Brief explanation of Knowledge Management (optional);
- Brief explanation of what is Knowledge Mapping (if this is the first mapping);
- Presentation of the questionnaire structure;
- Presentation of the activity guides to the participants;
- Presentation of the questions on Knowledge Mapping.

Knowing the question of the knowledge mapping helps us to focus on the knowledge that we want and to capture accurate information, aiming to avoid extracting information that has nothing to do with the knowledge we demand.

3.1.2 Knowledge Mapping Questionnaire

The Knowledge Mapping questionnaire has a logical structure that seeks to find three aspects: what activities the participant exerted during the execution of the project, what or who (s)he researched to acquire knowledge and who (s)he helped.

Participants must be left free to consult each other, and they must have available resources to consult when they have questions while filling out the questionnaire. The reason for using these resources is that some people may not be able to remember some relevant information.

The first part of the Knowledge Mapping survey (see Figure 2) is related to the **Applied Topic of knowledge** of the activities (s)he carried out. The purpose of this information is to know what knowledge (s)he applied.

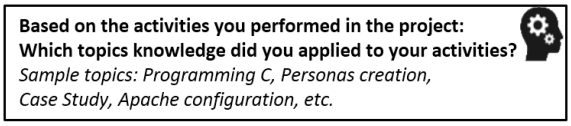

Figure 2: Field to describe which activities were conducted.

The field in Figure 3 is related to **Who /What (s)he consulted** to carry out his/her activities. The participant may indicate if (s)he consulted a person or an artifact and they should describe the name of the consulted person or artifact in the "Name of Person or Artifact" field. Then s/he must complement with a brief description regarding what was consulted. Some fields present different sizes because it might be possible that the participant has more than one consult to a device or person.

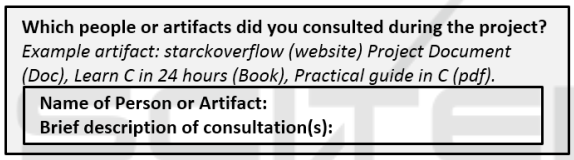

Figure 3: Field to describe the consults that were performed.

Finally, the participant must inform in the field shown in Figure 4 **Which people (s)he helped** during his/her activities. Based on this and the previous field, we can triangulate the information aiming to find the flow of knowledge among participants and to know what kind of knowledge takes place among them.

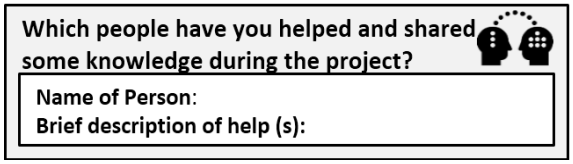

Figure 4: Field where the participant informs who (s)he helped.

3.1.3 Artifact Analysis

The artifact analysis is defined as the analysis of information from project-related documents that may be potential sources of knowledge. Its purpose is to explicit knowledge sources that will integrate the knowledge map.

3.2 Mapping Phase

The mapping phase will analyze the collected data in the data collection phase and will generate the knowledge map of the project team. Initially, we organize all the collected data on a table, as shown in Figure 5. Then, we produce the representation of the knowledge map sources (either by using physical materials with a whiteboard or through digital tools). Finally, we will generate the profile of each participant.

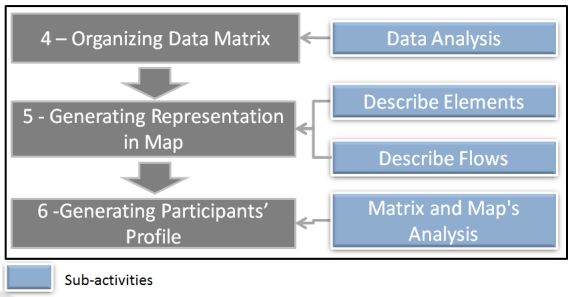

Figure 5: Activities from the Knowledge Mapping Phase.

3.2.1 Organizing the Data Matrix

Mapping questionnaires are analyzed at this stage and the moderator, who is implementing the Knowledge Mapping process, should examine each of them as (s)he carries out the parallel activities of this phase.

In the actors-artifacts relationship (where the actors are the participants), we organize all the data in a table following the format in Table 2. In the horizontal lines, we insert all the names of the project participants that have been mentioned in the fields "who you consulted" and "who you helped" from the questionnaires.

Table 2: Structure of Actors-Artifact in the Data Matrix.

Actors	Participant 1	Participant N	Artifacts	Artifact 1 (Type)
Participant 1		Id 1		Id 2
Participant N				

The columns are filled with the same name of the participants defined horizontally. After dividing the "artifacts", we can enter the names of the mentioned artifacts by any participant within the questionnaires.

While reading what artifacts were mentioned by the participants in the questionnaire, we should avoid duplication and then generalize when two participants refer to the same artifact. For example, two participants can mention the Stackoverflow online forum of questions and answers differently,

where one says "**Search Stackoverflow forum**" while another says "**stackoverflow.com**". Both participants refer to the same artifact, the Stackoverflow forum, so we will not insert two different columns for it. Instead, we can name the same column as "**Stackoverflow (website)**", where the parentheses in keyword help identifying what this artifact is.

After finishing to fill out the table, the cells are filled with an identifier of the description of the consulted information by the participant. For this, we will use a table for supporting where we will store the consult description gathered in the fields "who you consulted" and "who you helped" from the questionnaires. It is exemplified in Table 3.

Table 3: Structure to assist description of relationships.

Id	Relationship description	Participant
1	Description of Id 1	Participant 1
2	Description of Id 2	Participant 2

Finally, we have the name of the participants horizontally, while what they accessed (whether it is other participants or artifacts) is shown vertically.

3.2.2 Generating Representations in Map

The representation on the map can be done by a support tool which must have the following characteristics:

- Change colors or pictures of the node;
- Create edges between nodes;
- Assign weights and Text on the edges;
- Assign texts to the nodes.

After choosing the tool to be used, the activities of the process of knowledge mapping creation are initiated.

Based on the Data Matrix information built in the previous activity, we will perform the following steps to build the map:

1. Write what project members are;
2. Write what the artifacts informed by the participant are;
3. Center map members and leave the artifacts at the edges;
4. Insert an edge between nodes, namely between a member and an artifact, or between members;
5. Assign which or what are the relationships from such edge, based on the auxiliary table of the Data Matrix called Relationship Description;
6. Repeat from step 4 until all edges are created;
7. Document the map and its version.

After that, it is estimated that this map shows which members consult others and about what, and what artifacts are found during a project. It is recommended the review of the map by a second person in order to avoid omissions or errors.

3.2.3 Generating Participants' Profile

The profile of the participants is a representation indicating what skills or competencies (s)he is applying. They reference not only what (s)he informs, but what other participants inform. The map should also show how we can find him/her, what knowledge (s)he masters, what his/her sources of knowledge are and with whom (s)he communicates.

To generate the participant's profile, we will use the Data Matrix information, the analysis of the artifacts and the Knowledge Map as basis looking for:

- What are the main topics of knowledge (s)he employed in his/her activities?;
- What sources of knowledge does (s)he use?;
- What people has (s)he worked with or had some knowledge flow?.

This information will fill the items about the participant's profile in Table 4.

Table 4: Participant Profile structure.

Participant Name	<The full name entered by the participant.>
Position or Role	<Position or role of participant.>
Email	<Participant contact E-mail.>
Telephone	<Participant contact number.>
Keywords of major skills	
<Keywords that describe he/she skills. The keywords are the codes identified below.>	
Knowledge sources	
<What sources of explicit knowledge he/she consult based on the knowledge map.>	
People whom (s)he is related in the map	
<Which people the participant has a knowledge transfer based on knowledge map.>	
Worked projects within the Group	
<Project works within the research group.>	
Knowledge flow	
<The topics of knowledge informed by the participants.>	
Knowledge in…	
<Knowledge flow code.>	<Full description of flow.>

The fields Name, **E-mail**, **Position or Role**, and **Telephone** are extracted from the information previously collected. The information from the Knowledge Sources field will be collected analyzing

the data matrix based on the columns of the artifacts that the user entered. As shown in Figure 6, we use the participant's line and check the column of the artifacts used by him/her. This will be the information that will compose the field.

The **people to whom (s)he is related in the map** field will consist of all participants and people outside the project with whom the participant had any knowledge flow. In addition to identifying the participants, we assign weights according to the total sum of the flows between two participants, as seen in Figure 7.

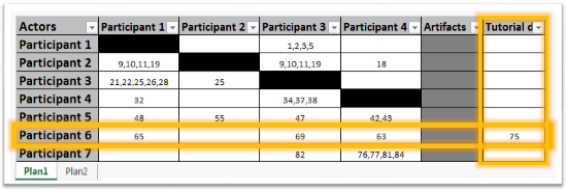

Figure 6: Capturing information about artifacts used by a participant.

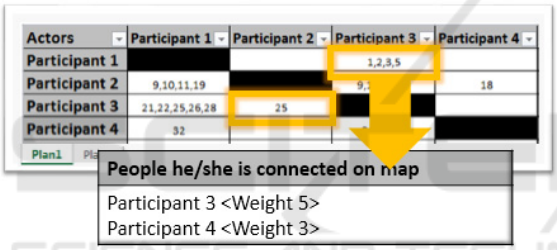

Figure 7: How to identify people connected to a participant.

Regarding the **Worked projects within the Group** field, this information will be extracted based on the analysis of the artifacts. In case that there is no identification, the field is filled with "None identified".

The **Participant Knowledge Topics** is the information that participants provided in the knowledge topic field of carried out activities in the questionnaire research, Subsection 3.1.2. After entering the information, we will generate codes for what was inserted. In addition, two descriptions may belong to the same code and thus increase the weight of this information, as seen in Table 5.

Knowledge flow will be the cross analysis of the Data Matrix for each participant (see Figure 8). The reason is that while the row shows just what the participant said, the column complements what others have reported about him/her. The Id (identifier) and his name should be placed in sequence in the field to be codified in the future.

Table 5: Knowledge topics of a participant.

Participant Knowledge Topics	
Review of material on Molic interaction modeling; Mockups together with Molic (diagrams); Case studies; Defects inspection; Inspection techniques for Molic diagrams; TAM (Technological Acceptance Model).	
Molic (3)	• Review of material on Molic interaction modeling; • Mockups together with Molic (diagrams); • Inspection techniques for Molic diagrams.
TAM (1)	TAM (Technological Acceptance Model.
Case studies (1)	Case studies.
Defects inspection (1)	Defects inspection.

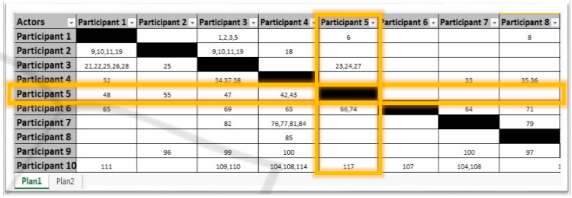

Figure 8: Way to capture the flow of knowledge from one participant.

After entering all the flows belonging to the participant, we will code with words that identify a concept or represent these flows (see Figure 9). The **Knowledge in …** field will be composed of all the coding of flows. Some encodings may have more than one flow, and the flow may belong to more than one coding.

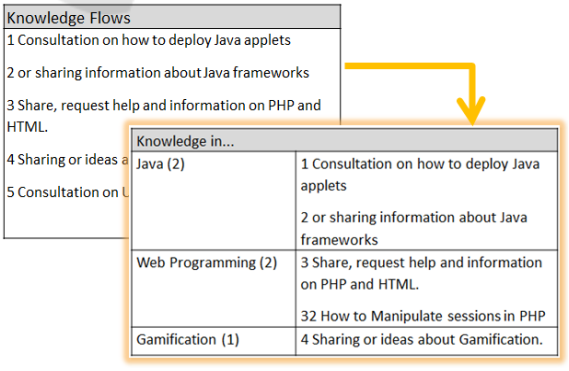

Figure 9: Analysis and codification of knowledge flows.

It is recommended the execution of codification by someone with knowledge of the organizational culture. Thus, the creation of codes is closer to

reflect the reality of the organization.

4 PILOT STUDY IN A RESEARCH AND DEVELOPMENT GROUP

The focus of the pilot study is to conduct a feasibility study of the Knowledge Mapping process. The primary purpose of a feasibility study is not to find a definitive answer, but to create a body of knowledge about the application of the technology (Mafra *et al.*, 2006).

As a result, we gain knowledge regarding if the process we are developing is feasible, if it produces a consistent result while identifying its limitations which, according to Shull *et al.* (2004), allows:

- The refinement of technology;
- The generation of new hypotheses on the application (in this case, the process of Knowledge Mapping) to be investigated in future studies.

The pilot study was applied in a software engineering and usability research group, which is formed by six Ph.D. candidates and four master students working on research and development in the areas of Software Engineering and Human-Computer Interaction. Thus, there are representatives of the population and, because it is a pilot study, we sought first to carry out the study within the research group and then evaluate in an industrial environment. The focus of the knowledge map was to find information related to types of knowledge that participants had applied or were applying in their research or in R & D (Research and Development) projects.

4.1 The Steps of the Pilot Study

The pilot study followed three steps detailed below.

1. Preparation: Contains the pilot study design, the creation of instruments and training of possible applicators of activity of Data Collection;
2. Implementation: The group in which the proposed technology would be applied attends a meeting in order to collect data. In this case, the Knowledge Mapping process;
3. Analysis and generation of results: The collected information will go through the data analysis of the Knowledge Mapping process.

By running the pilot study, we can verify the main aspects required for the application of the proposed technology (the process of mapping of knowledge) and analyze its limitations to evolve it in the future.

4.2 Preparation

In this phase, we plan and prepare all the instrumentation and contact the people that are necessary for the implementation of the Knowledge Mapping process. The main purpose of the preparation is to address threats to validity. Based on the recommendations by Wohlin *et al*. (2012), the following threats were addressed:

Internal Validity (Instrumentation): This is the effect caused by the artifacts used in the execution of the experiment. In the case of a poorly-planned experiment, its results will be negatively affected. Thus, a second researcher reviewed the artifacts created by the author process.

Construct Validity (Expected Experimenter): The author of the knowledge mapping process can consciously or unconsciously cause bias in the results of a study based on what (s)he expects the results of the experiment will be. When implementing the experiment, we asked another researcher with no involvement in this research to apply the process. However, in the analysis phase and the generation of results, the author of the process performed the analysis.

External Validity (Interaction of Participants and Treatment): It occurs when a sample does not represent the population we want to generalize. The focus of the process is to map software project teams. We chose a research group and R & D (Research and Development) projects due to convenience and the similarity of their themes and situations.

4.2.1 Instrumentation

For the pilot study, the following instruments that supported the whole process were developed:

Approach Manual: a Knowledge Mapping process manual was prepared explaining step by step how to apply and generate a knowledge map, how to collect data, which tools to use and what the end products of the process would be.

Knowledge Mapping Questionnaire: a questionnaire that aims to capture key information needed to generate the knowledge map and profiles of the participants.

Presentation of the Mapping Guide: a presentation guide that supports the moderator when applying the questionnaire and participants during the data collection. The presentation consists of 12

slides that show the objectives of the data collection, the structure of the questionnaire and a behavior guide for participants to follow during the session.

4.2.2 Guest Researcher

A researcher with no relation to the research was asked to administer the questionnaire to the participants. At a meeting, the author of the proposal presented the research objectives, the guide of the approach and the tools (questionnaire and presentation) for the guest researcher.

Additionally, we collected suggestions from the invited researcher to better conduct the experiment, which allowed gathering initial feedback for the improvement of the technical instrumentation. After the transfer of information, the execution of the study was scheduled with the group of participants.

4.3 Execution

Execution is the application of knowledge mapping questionnaire with the participants that will create the knowledge map. The questionnaire was printed and distributed to participants with no time limit to fill it out, and we allowed the interaction among them. The guest researcher assumed the role of facilitator, which sought to conduct all data collection and answer questions from the participants.

The participants took around thirty minutes to answer the questionnaire. The author of the proposal was absent during the execution process of the data collection in order to avoid any bias in the pilot study. After finishing the execution, the data was delivered to the author of the process for analysis.

4.4 Analysis and Generating Results

We explain the performed data analysis in this section. The results are related to the knowledge map of the team and the profiles of participants. For the execution of this phase, we did not invite another researcher, because the process needed a closer analysis from the authors of the proposal.

At this stage, all the Knowledge Mapping phase must have been executed, as described in Subsection 3.2, for the activities of **Organizing Data Matrix** and **Generating Representation in Map**.

For the **Generating Participant´s Profile** activity, which is the analysis and creation of all profiles, there is no reliable estimate to be informed due to the improvement of the technique while performing the activity. We explain the results of this pilot study in the following section.

5 RESULTS

This section presents the results of the implementation of the Knowledge Mapping process. In addition, lessons learned and results of the implementation of the knowledge mapping process are presented.

5.1 Knowledge Mapping Results

As presented in Section 4.3, in the execution of the study, we employed a printed questionnaire (subsection 3.1.2) with ten participants in an R & D (Research and Development) group. Ten questionnaires were analyzed in the mapping stage. A spreadsheet was used to support the creation of the Data Matrix.

For the matrix, two tabs have been created. The first one shows the connections between participants with participants or artifacts, as described in Subsection 3.2.1. A sample result can be seen in Figure 10.

Actors	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Participant 1			1,2,3,5		6
Participant 2	9,10,11,19		9,10,11,19	18	
Participant 3	21,22,25,26,28	25			23,24,27
Participant 4	32		34,37,38		
Participant 5	48	55	47	42,43	
Participant 6	65		69	63	66,74
Participant 7			82	76,77,81,84	
Participant 8				85	

Plan1 Plan2

Figure 10: First tab of the Data Matrix.

The second tab stores the description Ids generated in each cell. Moreover, it stores the participant's name and if the data is going in or out Figure 11).

Id	Description	Helped(<)/ Consulted (>)	Participant
1	Help in the division or material for interaction modeling	<	Participant 1
2	Sharing information on technical proposals for inspection Mo	<	Participant 2
3	Sharing and request help information about GT and TAM.	<	Participant 3
4	Sharing ideas about gamification.	<	Participant 4
5	Consultation on TAM's information and GT	>	Participant 5
6	Consultation on statistical test information	>	Participant 6

Plan1 Plan2

Figure 11: Second tab of the Data Matrix.

Then, we generated the graphical representation of the Knowledge Map based on the steps described in Subsection 3.2.2. We applied the NetMiner 4.2.1 tool due to its ease of use. The generated result can be seen in Figure 12.

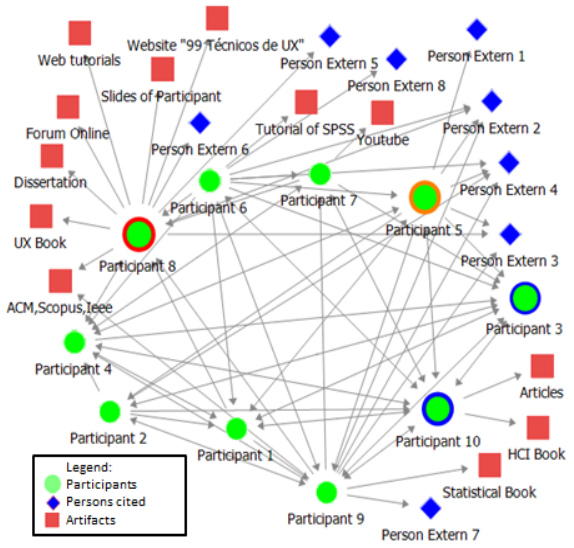

Figure 12: Group map generated by NetMiner (available at: http://www.netminer.com/).

The map elements were created based on the Data Matrix. As recommended in the approach's manual, participants were centralized on the map and indicated people or artifacts were allocated at the edges of the map.

Knowledge maps can provide a set of knowledge sources and flows. In addition, managers can use this information for decision-making. However, it is important to carry out a systematic analysis of such knowledge maps to reveal relevant insights of the organization (Chan and Liebowitz, 2005). Consequently, we applied Social Network Analysis (SNA) to systematically investigate some aspects of knowledge flow depicted by the knowledge maps.

In the map, we identified two central connectors. The central connectors are people with whom other participants interact more (Cross and Prusak, 2002), they are the participants from 3 to 10 (green circle with a blue border in Figure 14). Participant 5 is classified as Border Key (Cross and Prusak, 2002), which communicates with more people outside the network and serves as an ambassador between the network's internal and external knowledge.

We can check the level of reciprocity that is the similarity between the entries of two participants (Tichy *et al.*, 1979). The strongest connections are between the participants 1 and 3, followed by the participants 9 and 10.

Additionally, we can analyze that Participant 8 behaves like a person with the most access to artifacts (Red border in Figure 14). Moreover, Participant 5 (Orange border in Figure 14) is the person who consults the higher number of people within the network, which may be an indicator that (s)he had the current highest level of learning.

After creating the knowledge map graphically and in the matrix, we analyzed and generated the profiles of the participants based on the steps of Subsection 3.2.3. We define the key words that represent the main competences of each participant and using such information, we identified his/her and the group's main knowledge. Table 6 presents a profile created for one of the participants.

Table 6: Profile from a participant.

Participant Name	Participant 10
Position or Role	PhD student
Email	XXX
Telephone	XXX
Keywords of major skills	
Systematic Literature Review (6), Paper Writing (4), Statistical Analysis (3) Usability (3) Pilot Study (3), Modeling themes (3), Review proposal (3).	
Knowledge sources	
• ACM; • Scopus; • Ieee; • Books of HCI.	
People whom (s)he is related in the map	
• Participant 9 < Weight 7> • Participant 6 < Weight 7> • Participant 4 < Weight 4> • Participant 3 < Weight 4> • Participant 3 < Weight 3> • Participant 5 < Weight 3> • Participant 2 < Weight 2> • Participant 1 < Weight 2>	
Worked projects within the Group	
None Identified	

Finally, we produced the two main products of the Knowledge Mapping process: the group's knowledge map and a set of profiles for each participant.

Group leaders received the data for analysis and assessment. Moreover, the analysis of the participants, based on the maps and in the matrix, includes: who accessed other participants, who accessed more artifacts, which participants had the strongest connection (edges or knowledge flow) and what the strongest knowledge domain of the group was.

5.2 Lessons Learned of the Knowledge Mapping Process

We requested the participants to answer the questionnaires based on the main question of the mapping. Thus, the questionnaire words and

examples should be according to the defined mapping question.

The participants must be free to communicate with each other, so that they can easily retrieve information when filling out the questionnaires. Research on books, websites or document names should be allowed for a richer filling of the questionnaire.

During the mapping step, the matrix was modified based on the original idea with respect to the field describing the relations. A column with the name of the participants was inserted to provide a better way of identifying who owned that description in a bigger data set.

Once completing the knowledge map, we started the creation of the profiles from the participants. In the beginning, the first version of the proposed structure did not work to generate the profile of the participants. This was due to the lack of a review process of the results for filling fields correctly.

Improvements in the participants' profile form were: 1) The structure has been redesigned to display necessary information from each participant profile. 2) A knowledge technique for identifying the applied knowledge of the participants was defined to analyze the flow of knowledge among the participants. 3) The steps of the analysis and profile creation activities have been rewritten. The main goal for such change is that others can properly apply the process without help or interference of the authors of the process.

6 CONCLUSIONS AND FUTURE WORK

The Knowledge Mapping process presented in this paper maps a group of participants and creates profiles for each participant. In addition, we carried out a pilot study where it was found that this process is feasible.

Each profile displays, besides basic information on how to find the participant in the organization, with whom (s)he is connected to on the map and what activities (s)he performs. The profile also displays indicators of the main competences (s)he is carrying out in the group using information that other participants employ from him/her.

The executed knowledge mapping process within the study produced a map where one can check which connections a participant has with each knowledge source, either being explicit (websites, books, and so on) or tacit (access to people). Also, it is possible to check on each edge which knowledge is flowing.

The advantages found to justify the creation of a knowledge map in the study are:

- To check what main competences a participant is in fact executing. Based on this, we can verify if (s)he is applying something for which (s)he was designed or if there are any mistakes in the execution of his/her activities;
- To check for anomalies in the knowledge flow of a participant. Perhaps a participant is requiring a source of knowledge that does not fit into his/her roles. It can mean a learning signal or irregularity;
- To check if the flow of information between members is happening. In an integrated team, we can see through a map if two members are or not interacting when they should be. For example, the analyst responsible for gathering requirement and the developer;
- To identify the current knowledge in a group or software team. Based on the identified keywords within the profiles, we can draw conclusions from what knowledge the group or team is employing and which have high scores.

Finally, as future work, we intend to:

- Apply the Knowledge Mapping Process in a Case Study with software projects teams;
- Automate the data analysis process and the creation of profiles;
- Compare Knowledge Mapping with network analysis techniques such as Social Network Analysis;
- Apply the Knowledge Mapping Process in a Knowledge Audit Process as Elias *et al*. (2010).

ACKNOWLEDGEMENTS

We would like to thank the support granted by CAPES; by FAPEAM through processes: 062.00600/2014; 062.00578/2014 and by CAPES process AEX 10932/14-3. We would like to thank all the subjects who participated in this study.

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