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Understanding the Process of Knowledge Transfer in Software Engineering: a Systematic Literature Review

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***Abstract*— Purpose - There has been an increasing interest about knowledge management in software engineering last years, most of the attention has been focused on knowledge codification and sharing, but less in knowledge transfer. The purpose of this paper is to make a general review of the work done about knowledge transfer in software engineering. Design/methodology/approach – An opportunistic systematic literature review protocol was made, looking for answer the question about what the topics are studied knowledge transfer in software engineering as a whole, which parts of software engineering needs deeper study and how knowledge transfer could be measured. Findings – Knowledge transfer in software engineering studies could be classified in two parts: firstly the companies size (multinationals, big, medium and small) and their social capital, and secondly the software process, where were found out that software requirements have not been deeply studied since the knowledge transfer perspective. Referring measurement, it was found out that is a topic still in his infancy. Originality/value – This paper use a systematic revision protocol to better understand what work has been done concerning knowledge transfer in software engineering, and argues why more attention is needed for the knowledge transfer in software requirements.**

Keywords-component; Knowledge Transfer Process; Knowledge Management; Software Engineering; Systematic Review

I. INTRODUCTION

Software Engineering has been recognized as a knowledge intensive application discipline [1], [2] and [3]. For this reason, in the last decade there has been an increasing interest about knowledge management in software engineering. In particular, the processes of knowledge codification and knowledge sharing have received most attention and they have been researched in diverse ways. Other authors have argued about the relevance of knowledge transfer processes in knowledge management [4] [5] and the importance of knowledge transfer in software engineering [6] , [7]. In this sense, there is a consensus about the importance of the knowledge transfer process, however, there is still a debate among what the knowledge transfer process really is, because knowledge is not only tangible and linked to cognitive processes inside people's brains but also is said to be particular for everyone [8], [9] therefore, is not easy to measure.

Along this line of thinking, the purpose of this paper is to present a systematic literature review of research publications on knowledge transfer process in software engineering. The goal is to synthesize important aspects of the implementation of knowledge transfer process in different levels like cross-national organizations, software engineering projects or between individual members of software engineering organizations. Also, taking into account the influence of agile software development on industry practice today is relevant to inquire into knowledge transfer practices in agile models. Finally, we want to gain insights on how knowledge transfer process could be measured. More specifically, the research questions for this study are:

1. How the knowledge transfer process has been implemented in different levels in software engineering organizations?
2. How the knowledge transfer process is conceived in agile software development?
3. How the knowledge transfer process could be measured?

In developing this paper, we start with a background about knowledge transfer in section II. Next in section III the systematic literature review research method is described. Section IV presents the results of the systematic literature review for each research question. And finally, in section VI the conclusions of this study are presented.

II. A THEORETICAL BACKGROUND ON KNOWLEDGE TRANSFER

A. Knowledge Transfer concept

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On the one hand, knowledge has been defined as the information and experience grouped usefully in some context [10], and literature shows a consensus about the taxonomy which represents knowledge as tacit and explicit [9]. On the other hand, transfer means to pass an element form one side to another [11] and [12], so, knowledge transfer means to pass useful information and experience from one context (project) to another (inside or outside of an organization).

Nevertheless, such transfer, according to some authors, cannot be done [13] due to the fact that knowledge is personal and unique. Every time knowledge passes from tacit to explicit, new knowledge is generated so it is different from the previous one [14]. In this way, the exactly transfer of knowledge cannot be possible.

It should be noted that knowledge transfer (KT) is different from knowledge sharing [4] [6], since the fact that a person shares knowledge does not mean that he/she already did a transfer. Consequently, entity A (person, business unit or company) transfers knowledge to entity B, just when B is able to apply it in a useful way in its own context, as shown in Figure 1. By the same token, it can be said that only sharing knowledge has occurred.

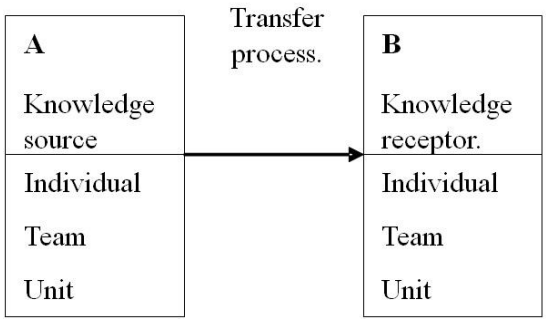

Figure 1. Basic model of knowledge transfer. Adapted from [4]

Knowledge sharing is important as a KT enabler, but sharing alone is not enough to make transfer occurs. This is remarkable because, until now, the greatest advances in knowledge management applied to software engineering have been done at the level of knowledge sharing using knowledge codification [14], [15], [16] and [17].

KT is more than mere codification because it demands more than building "knowledge" bases (data and information) [4]. Those bases ended being only data repositories because those bases are used just to code the knowledge, however KT is related to a human process and it could only be generated through cognitive process inside people's mind [18].

B. Knowledge Transfer as a Process of Knowledge Management

KT is one of the most important processes for knowledge management [19], their activities are mainly three, gather the knowledge from a source, code it through a channel, and pass it to a receipt [5]. KT inside the knowledge management could be seen as a final process, because after create, store and share the knowledge, only when transfer occurs knowledge management makes sense and could be said that is useful [6] and [4], otherwise –from that point of view- knowledge management is just an effort to create a repository of knowledge .

KT process could be depicted as a source of knowledge who has explicit or tacit knowledge and a receipt who has to interpret the knowledge so it is able to apply knowledge transferred, Figure 2. Knowledge transfer as a process. **[5]** shows that process. It is important to note that for transfer success, Knowledge codification at the source must to be done, because the knowledge at the source, even if explicit, has to be codified in an object with significance for both source and receipt.

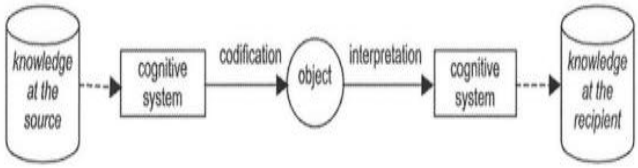

Figure 2. Knowledge transfer as a process. [5]

C. Knowledge Transfer Barriers and Enablers

KT has barriers and enablers inside an organization, such barriers are related to economic, cultural and social capital [20]. Depending on the type of organization some factors are more relevant, for instance in multinational environments, culture differences are more important than in small and medium environments [21], [22] and [23].

The barriers/enablers factors influencing KT usually come from hypothesis about people behavior, is used to presume that for KT occurs, a predisposition of the people to share knowledge should exist [24]. Typically, factors always have two components, one organizational and one technologic. The organizational is used to measure people and business unit's readiness towards knowledge management, and especially towards KT. The technology is used to see how far could exist collaboration tools and knowledge bases to support the KT process.

Majority of the research has been done using surveys trying to determinate the effectiveness of the methodologies applied for the KT, those surveys are used to be created from a proposed model and are validated by sending it to different companies. Ideally some authors propose consistence indexes to measure the gathered responses and

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the questions integrity [25]. Additionally, some authors by using surveys found interesting behaviors such as that people interviewed usually are willing to share their knowledge and emphasize the importance of knowledge sharing to carry out their activities [26] and [20], and encourage to reapply previous surveys in local environments to verify and to validate their questions and answers [3].

Table 1 presents a parallel between the organizational components mentioned by the authors, such as the organizational culture, the leadership factor within the projects, the trustiness inside the work team bosses/subordinates and the incentives that the organizations brings to people who share their knowledge. Also it is shown the technology tools mentioned by authors to carry out the knowledge transfer. Such technological tools are focused on communication between people: using IP technologies to mitigate the distance effect; social networking software or socio technical networks, or workflow. Together with databases that store information "experience bases"; wikis that give information about projects, their technology and how it was applied; frequently asked questions with details of the technology used, yellow pages to find experts and web pages to share more information.

Table 1. Knowledge transfer enabling factors.

Organizational factors	Knowledge management tools
Culture Leadership Trustiness Incentives	Collaboration tools (IP telephony, VoIP) GroupWare Socio technical networks Ontologies Experience bases Wiki FAQs Yellow pages Web Sites

Figure 3 depicts the importance of organizational factors joined with a set of technology to facilitate the KT, it appears a social space and socio technical nets, junior, senior and expert teams because it is natural that people relate between each other. Besides, there are communication tools and knowledge repositories with codified knowledge, where finally a facilitator appears on the middle in order to help the articulation between the members, that articulation means to serve as a bridge to join the teams/people who need certain knowledge with the teams/person who owns the knowledge, in order to provide support for new ideas, requirements or projects. The weak or strong tie from the groups with the facilitator are represented by a dotted line, this means there are certain groups who already have not access to the required knowledge.

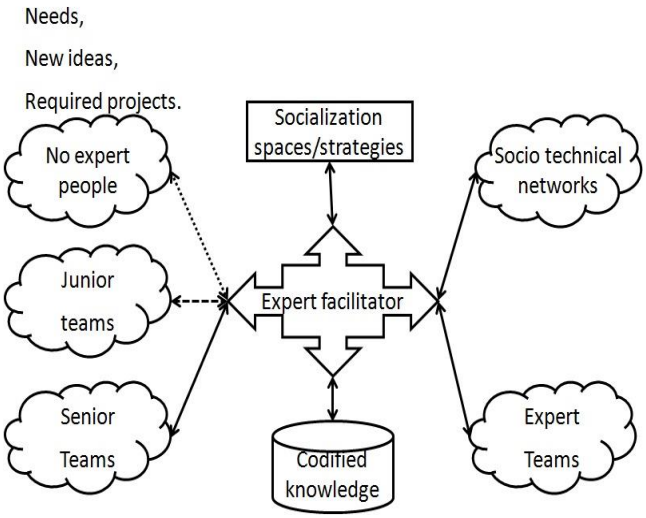

Figure 3. Knowledge transfer mixed techniques. Experience base and people networks. Based on [27]**.**

III. METHOD

The research method used as a guide for this review is the proposed by [28]. This method starts with a review protocol which deals with: the specifications of the research questions, which are described in the introduction of this paper; the search strategies which are described in section A; the study selection in section B; the criteria for quality evaluation of selected studies as shown in section C; and the data extraction that appears in section D.

A. Searching strategies

The searching strategies definition comprises two elements: information sources and searching expressions used in the search engines provided by the selected information sources. The information sources for this systematic review were selected because they collect most of the scientific production in the field of interest. The selected information sources are: *SCOPUS*, *IEEE Xplore Digital Library*, *Emerald*, *ISI Web of Knowledge* and *ACM Digital Library*.

In addition, the construction of search equations was developed iteratively, building "prototypes" of terms and expressions. This activity resulted in a search expression with keywords, phrases and boolean operators. The final search equation used in this review is as follows:

"*Knowledge Transfer"* **AND** "*Measure Performance*" **OR** "*Knowledge Transfer* **AND** *Software Engineering*" **OR** "*Knowledge Transfer* **AND** *Software Project*" **OR** "*Knowledge Transfer* **AND** *Metric*" **OR** "*Knowledge Transfer* **AND**

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Software Engineering" **OR** "*Knowledge Sharing* **AND** *Software Performance*" **OR** "*Knowledge Sharing* **AND** *Performance*" **OR** "*Knowledge Sharing* **AND** *Software Engineering*"

Using the search equation in the search engines of the selected information sources we find 608 "potentially relevant" papers. Then, after debugging the results by duplicate cleaning, 461 unique papers remained.

B. Study Selection

In making the selection key words transfer and sharing were used interchangeably because the continuous debate among these two terms in literature, even though the difference made in the background of this paper, differentiating transfer from sharing.

The search equation result in 608 papers potentially relevant. After debugging the results for duplicates, 461 unique papers remained. Then, by fully reading abstract, introduction and conclusions 91 articles were marked as accepted for read their full text, and 27 was marked for the quality review. Once the quality review was made, they were 26 papers for data extraction.

In short 65 papers were rejected due to their lack of evidence and for not doing emphasis in the research questions.

C. Quality Assessment

For the quality assessment, seven set of questions were done, those sets aim to filter the papers to give according relevance and pertinence for this paper interest questions. In doing that, the sets evaluate: the papers objectives and context of the research; methods discussions, data collection, data analysis processes to support the results, bias debate, results discussions and research value.

D. Data Extraction

For the data extraction, two structures were developed: the first one about general information as the study description of the paper, and KT related to concepts. General information comprehends: the bibliographic reference; the paper type; the study finality; objectives of the study; the study design i.e. qualitative or quantitative; the hypothesis if any or the theme developed as action-research; KT definition; the sample description in terms of size, age, experience, etc; the study area stating industry, in house development, products and processes used; the data collection as how data were extracted i.e. questionnaires, interviews, etc; the data analysis to keep the research type i.e. qualitative or quantitative; and at last but not at least keep record of the model, methodology for KT used.

The second structure concern papers results: word for word of the results and conclusions; record of the limitations stated or threats to validity; finally the relevance of the paper both for research and practice perspective.

IV. RESULTS

Responding the questions proposed in the introduction, the KT environments appearing in software engineering papers were sorted according to different levels in a software developing organization: the multinationals, between projects and between people and agile models. Those environments describe what has been written about KT related to software engineering and are described in section A. Answering question two, a description about what have been written about KT and agile methods is done in section B. At last, in order to answer question 3, section C presents what was found about KT measurement.

A. Knowledge Transfer In Software Engineering

Answering the first question, how have been seen KT in software engineering? This section presents five elements found where KT takes place inside software engineering.

First of all due to the intensity of the use of knowledge in software engineering [29] and [25], the software engineering processes are at an interesting place for KT study. A general view of a software development process could have five phases (requirements, design, development and testing, integration and maintenance) with the classic cascade model [30] [24]. KT in the classic cascade model Figure 4 will be explained below.

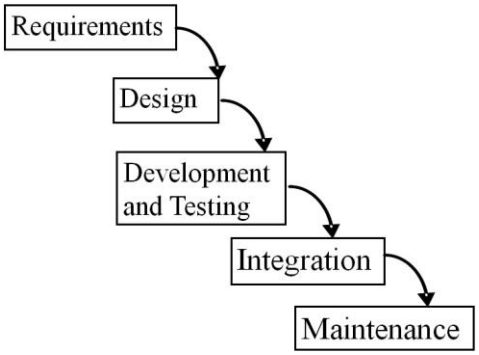

Figure 4. Cascade model. Adapted from [30]**.**

Although the cascade model could be seen obsolete nowadays, certain authors [24] continue referencing it because other models have appeared based on this model, those models include some improvements, for instance:

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iterations, recursion or parallel steps, but in the end, the basic software development process phases are the same. These phases could be executed in different order or with a different focus.

KT could be seen starting along the software requirements phase, there is an interaction between the technical team and the costumers, which are the owners of the business knowledge. These costumers must transfer the aforesaid business knowledge to the analysts, so that they can design models that should help to transfer business knowledge to technical knowledge into models that describe the software (Class diagrams, components, etc.) (Havlice et al., 2009) and [3].

Likewise, within the technical team, KT occurs in software development (techniques and programming procedures) and software testing (test cases, scenarios, etc.).

Next sections will show the environments where KT has taken place according to the review done.

1) Knowledge transfer within software development multinationals.

In the literature review some articles which treat the topic of KT in multinationals were found; they all claim that very few research has been done on the topic in multinational environments, where, there is not only a distance issue, but also, cultural facts [21], [31] and [32].

Those authors do a list of possible factors that affect transfer in such environments, being the cultural factor the most troublesome. To avoid such difficulties, they define a mechanism to code the knowledge, for instance, internationalization tools to mitigate the idiomatic differences are made by coding and some others generate more sophisticated mechanisms as ontologies to define a common language.

With those codification and telecommunications tools, it is possible to facilitate KT, because those tools help to reduce physical and cultural gaps.

In brief, the topic of KT in multinational environments addresses the issue of information and experience transfer of successful projects from one organizational unit to other.

To carry out what was said before, authors state diverse factors and hypothesis that are supposed to increase the transfer effectiveness, where the principal role of technology in this aspect is to serve as an information repository with relevant information about the work to be done, as well as a collaboration tool to mitigate distance between people, [14], [21], [31], [26] and [33].

Figure 5 shows a set of common factors taken from the review. These factors expose characteristics that should be considered for an effective KT. It just shows factors at organizational levels, this means only elements that inside the organization administration can affect KT effectiveness. Promptly in the review, three groups of factors or dimensions were found out: structural, relational and cognitive [34]. ***The structural dimension*** deals with how the communication inside the organization is done; this communication can be formal or informal, depending on the communication channels that are used. For instance, one type of formal communication can be meetings or memorandums, by contrast, an informal way could be a socialization during a coffee break or the use of social networks. The second one is ***relational dimension*** which deals with factors of people and their culture inside the organization; such factors include the confidence between people, bosses and subordinates, the organizational commitment of these people, the remuneration capability of the organization and, the factor of the identity towards the organization and the work done. The last one, the ***cognitive dimension*** references the organization management to articulate strategies along all of the processes and people, together with a factor of organizational culture to provide the dimension mentioned above.

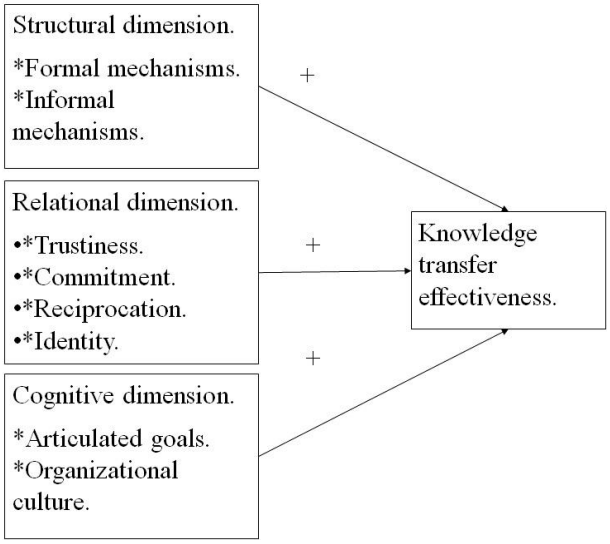

Figure 5. Knowledge transfer factors in multinational environments (1) Taken from [34]

Meanwhile, Figure 6 shows the coordination elements that influence the knowledge transfer. The idea is to see that it is not only necessary to take into account the organizational factors mentioned above, but also the technology that supports the knowledge transfer processes, especially, the ones related to mitigating extenuating factors.

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Such technology tools can be knowledge bases: repositories in relational or document oriented databases, with useful information about the business processes; collaborative tools: such as social networks and, in general, any technology that supports people communication and the building of collective concepts, such as blogs or forums [21] and [35].

Technology tools help to mitigate physical distance, because the internet/intranet does not require that the work teams stay together in the same place. In addition, translation tools and ontologies can mitigate ambiguity in the texts and idiomatic differences [36]. More importantly, there are face to face coordination methodologies (face to face meetings, for instance at the same location), which are traditional however they are more sensitive to the effects of geographic and linguistic distance [34].

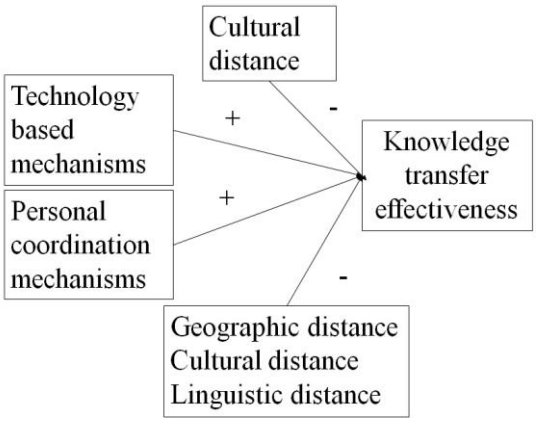

Figure 6. Knowledge transfer factors in multinational environments (2). Based on [21]

2) Knowledge transfer within the projects.

An interesting point of view for KT is that it can take place in an isolated environment inside the organization, which is important because it facilitates the processes given that the team is inside the same organization. In contrast, the transfer between organizations could be difficult due to intellectual protection issues, which prevent the flow of knowledge [37], [38], but inside the same non-multinational organization, the concern is to achieve a link between culture, processes and their supporting technology to facilitate KT [39].

Figure 3 shows the current methods used for KT. There are various groups of people that represent the projects that could have or not experts. These experts belong an expert net, which could be managed in a formal way through directories, where experts could be contacted for a topic, or could be undocumented nets, as friend or colleague nets. Ideally, such nets should be documented in a directory or software that leads to the experts. Likewise in Figure 7 appears a knowledge base with an ontology that defines the business process language. Such knowledge bases are useful to keep the history of the management done in the projects, and their goal is to preserve the best practices or key factors that have contributed to the success of the projects.

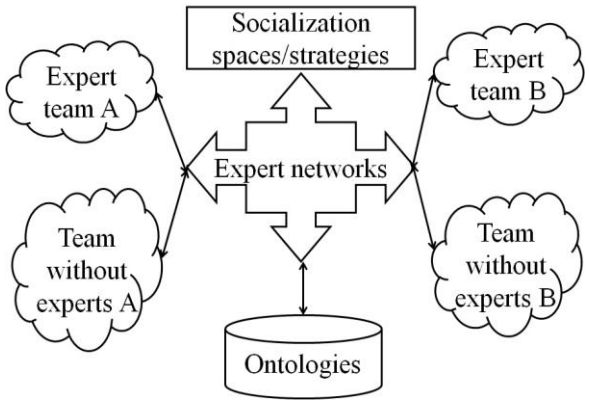

Figure 7. Experts net with a knowledge base. Based on (Schneider, 2009).

The concern here is to reproduce the knowledge by taking advantage of the experts in an organization or business unit, so the others could be benefited of their experience. It is not just about repositories with knowledge bases or ontologies that represent the domain of the problem, but the technology tools that must lead to the collaboration and access to the experts so that they could be reached through their documents and face to face, improving the KT [40]. This has not had a big development according to the review done, so it could be a good topic to research.

3) Knowledge transfer between people.

Finally, in a more atomic level, the KT between two people is studied. The SECI model [41], defines a series of steps that are followed in the learning process of a person. Which are: a) *socialization*, where a person A socializes his/her experience and knowledge with other person B; b) *exteriorization* occurs in person B when he/she can define concepts in their own context about the knowledge acquired; c) person B does *combination* when applying his/her new knowledge and builds prototypes, finally, d) the knowledge is internalized in person B through practice, so the knowledge becomes a part of his/her mental models, believes, abilities, etc. Into the previous general model of knowledge management, KT could be seen in the existence of two people; apprentice and master, where the apprentice in turn can be an expert in certain topics and a master can be an apprentice in others [25].This shows that in general any expert person may also has got the need of learning and acquiring new capabilities for different projects, in this case about software.

The idea of transfer between people is that they meet generally in an informal way, to treat the issues of the

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organization and give each other pieces of advice on how to carry out the work in the best way according to their experience. Like this, social methodologies were born, as the coffee breaks, where people get involved to share their experience.

Figure 8 shows this kind of interaction, where the idea is not a plain transfer, because of the personal nature of the knowledge, and instead of doing a transfer, what is done is building new useful knowledge in one or more contexts [8].

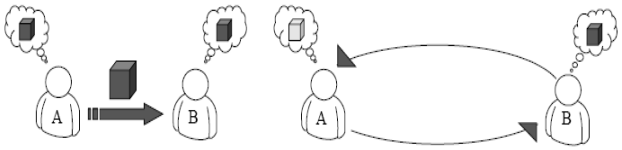

Figure 8. Modelo de transferencia de conocimiento. Taken from [25].

B. Knowledge transfer in agile models.

KT is evidenced by feedback between people. The agile models promise to decrease documentation in favor of coding speed, leaving the knowledge inside the people's head, however, it favors the knowledge flows while making periodic meetings [24].

Basically, one might think that an agile environment is more adequate to KT than a traditional one (cascade, RUP), in which a series of pre-requisites are demanded in order to advance to a posterior step.

Agile environments facilitate to share the knowledge because the teams work on iterations that allow a continuous feedback, not only inside the technical team, but also with clients and owners of business knowledge [42] and [43].

Regardless of the agile methodology, the idea is to favor the interactions between people instead of processes and tools, the software work instead of detailed documentation, the collaboration with clients instead of contract dealing and with this, to respond to the variant requirements as it progresses.

There are various agile models, and an abstraction of them could be seen as an iterative cascade model (due to the software development phases) iterative with multiple interactions. Although there is an iterative software model, the difference with an agile method is that iterations are done between little, very specific requirements/functionalities, and the traditional documentation is minimal. Figure 9 shows such interactions, in which KT is also performed, since it does not just involve a relation among developers, software testers and analysts, but includes the business owner and the expert in the process to be automated in KT [21], [44] , [45] and [46].

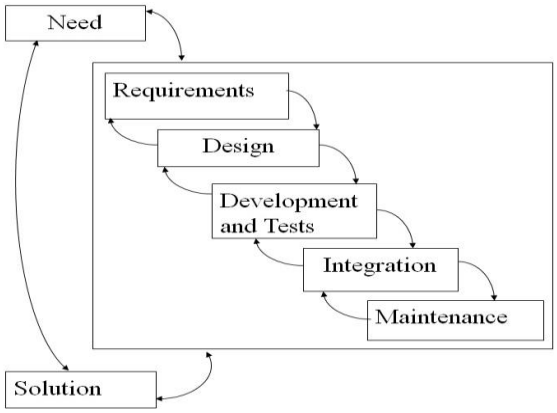

Figure 9. Agile model generalization. Based on [37]

C. Knowledge transfer measurement.

Answering question 2, about KT measurement, it was found in the literature that are few the metrics proposed. It is argued that KT is something difficult to measure, because it cannot be measured directly, and always is measured indirectly. If it is tried to be measured by the knowledge created, it could be a mistake due to the KT is not the only existing way to create new knowledge [25] and [24]. To deal with this, is used to ask for KT perception in the organizations and people.

The most common metrics are those who deal more with final elements more than the mere KT. For example, there are some authors who emphasize more in final products, innovation quantity or new concepts generated, however, it is not only with the achievement of final products or the generation of new concepts that it could be said that KT is successful [25].

Furthermore there may be more interesting metrics for the organization, for instance oriented metrics to the gaining of money or value generated, such as earnings that come after a project that had KT or even the return of investment over knowledge active, e.g. a patent [47].

Either the commercial value could be taken into account, for instance the gain of a new market, the client's satisfaction, gained clients, increased sales by clients etc. Another metric could be the value created by research and development activities and the return of invest by each trained employee (KT) [18].

Some metrics more oriented to KT, are focused on the quantity of knowledge (in knowledge bases) frequently acceded or reused. And measure how many people have shared their knowledge [48]. In short KT cannot be

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measured directly, but it is measured in a qualitative way using organizational and technological factors, together with final products obtained from such transfer [20].

It should be noted that the measurements are done by surveys from which the questions are related to the factors to measure, for instance, if it is desired to know if the transfer process X was effective, it is asked if the people consider that they could learn from process X and in turn if it was useful to be applied to certain project Y. To this some authors [25], [24] and [20] show examples of questions, but in general those kind of articles do not show the full questionnaires used in the organizations.

V. CONCLUSIONS

From the review done, it was found out that nowadays the knowledge management studies has been focused on the creation and codification of knowledge, later in their socialization or dissemination*("knowledge sharing"*) without taking if a real knowledge transfer occurs.

Taking into account question 1, how have been seen the KT in software engineering? In the existent literature about KT in software engineering, the principal focus has been:

- KT among software development multinationals.
- KT within projects in the organizations.
- KT between people within an organization.
- KT inside development teams, using agile models.

Given question 2, how could KT in software engineering be measured? The authors mentioned above typify some factors that facilitate KT. However they leave out any means of metric or indicator that permit to measure in any way KT rate.

On the one hand it is found out that KT in the process of requirements elicitation has not been widely studied in the literature, just four articles are directly related to it [49], [50], [51] and [52]. The phase of collection and specification of requirements play an important role because is where the business needs are translated to technical language and allow setting the scope of the software project [53] and [54]. The problem of carrying the business concepts across all the software development steps has not been studied and represents an interesting percent of fail causes (23% (Jørgensen, Østvold, 2005) in the software development projects. Even if the software chaos report from the StandishGroup has been criticized, and the 189% overrun percentage in software projects has been reduced to 34% and 33%, the 68% of projects that still fail are because of the poor requirements specifications.

On the other hand measure KT is a problem, because not exist any clear model that allow a quantitative and/or qualitative approximation to KT, specially due to the KT is not the only way to create new knowledge [4] and [37].

It is proposed that more research is needed about KT in software engineering and software requirements process is seen as the starting point for that endeavor.

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