Knowledge Management in Software Engineering – Describing the Process

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Abstract

The management of knowledge and experience are key means by which systematic software development and process improvement occur. Within the domain of Software Engineering (SE), quality continues to remain an issue of concern. Although remedies such as fourth generation programming languages, structured techniques and object-oriented technology have been promoted, a "silver bullet" has yet to be found. Knowledge Management (KM) gives organisations the opportunity to appreciate the challenges and complexities inherent in software development. This paper reports on two case studies that investigate KM in SE at two IT organisations. Structured interviews were conducted, with the assistance of a qualitative questionnaire. The results were used to describe current practices for KM in SE, to investigate the nature of KM activities in these organisations, and to explain the impact of leadership, technology, culture and measurement as enablers of the KM process for SE.

Keywords: *Knowledge Management, Software Engineering, process models, KM activities, KM process enablers*

1. Introduction

The concept of Knowledge Management (KM) reflects the transformation currently occurring in many organisations. The advent of the 21st Century has seen a greater need for organisations to become more dynamic, tempered by their ability to build upon successive experiences to improve business processes. Today, almost 80% of the world's largest organisations have implemented KM solutions [16]. However, knowing "what knowledge to manage is a significant challenge" [13]. Perhaps an even greater challenge is *how* knowledge can be managed, given the complexity of business environments and the demands they place upon individuals.

Software Engineering (SE) is a discipline that is yet to reach maturity, despite the tremendous amount of research it has engendered. During the 1990's, increased consideration was given to the process used for software development and its potential to improve software quality. The popularity of the Capability Maturity Model (CMM), ISO 9000 series of standards and the Software Process Improvement and Capability dEtermination (SPICE) model are testament to the importance associated with a process-orientation for SE [18]. The need to further develop SE practices within organisations adds to the demand for systematic knowledge and skill management at all stages of a software lifecycle [2]. The increased complexity of project work has also led to a greater reliance upon knowledge processes to solve problems [11]. Therefore, software developers are required to develop knowledge of emerging technologies, while at the same time ensuring that they adhere to organisational processes and methodologies. KM in a software organisation is seen as an opportunity to create a common language of understanding among software developers, so that they can interact, negotiate and share knowledge and experiences [2]. Furthermore, a KM system supports the ability to systematically manage innovative knowledge in software development.

In this study, the process-oriented approach to SE is extended to consider the KM process for SE. There is currently a gap in literature concerning the KM process for SE, particularly within an Australian context. The objectives of this study were (a) to determine current practices for KM in SE, (b) to describe activities that comprise the KM process for SE, (c) to identify high-

level models of the KM process for SE and (d) to establish the impact of leadership, technology, culture and measurement as enablers of the KM process for SE.

The remainder of the paper is outlined as follows. Some of the related work for this area is presented in Section 2. The research methodology is described in Section 3. Section 4 presents the results, which are then further discussed in Section 5. Finally, validity issues are introduced in Section 6 and concluded in Section 7.

2. Literature Review

2.1. Defining Knowledge

The definition of knowledge is one that has attracted a significant amount of conjecture [8]. Knowledge has been defined as an "understanding, awareness, or familiarity acquired through study, investigation, observation or experience over time" [6]. It has also been conceived as "justified personal belief that increases an individual's capability to take effective action" [1]. From the work of Polanyi [19] emerged a widely accepted classification strategy, categorising knowledge as either tacit or explicit. The performance of KM may also be assessed in terms of either personalisation strategies, for tacit knowledge, or codification strategies, for explicit knowledge [12]. Tacit knowledge cannot be easily codified, remains highly personal and is difficult to communicate with others [17]. In contrast, explicit knowledge can be formally expressed, is systematic in its application and can be readily processed [17].

2.2. KM in SE

SE knowledge is dynamic and evolves with technology, organisational culture and the changing needs of an organisation's software development practices. Kess and Haapasalo [15] argue that software processes are essentially knowledge processes, structured within a KM framework. Aurum et al. [2] point out that software development can be improved by recognising related knowledge content and structure, as well as appropriate knowledge and engaging in planning activities. Basili et al. [3] [4] acknowledge that for an organisation to implement the 'Experience Factory' (EF) approach for KM, a number of potential barriers to success must be overcome. They argue that while the EF is aimed at instituting a learning organisation, it requires a significant investment of time and effort. They stress the need to leverage alternate approaches to distribute knowledge quickly. The 'Answer Garden' approach is depicted as a short-term solution to questions that may not require extended responses. Johansson et al [14] apply an 'Experience Engine' approach to KM in SE, as a subset of the EF. They list problems identified with the EF approach, such as its experimental nature, the organisational restructuring it prompts as well as its reliance upon an experience base containing a vast amount of written documentation. They assert that experience is best transferred when the receiver is "actually doing something related to the experience being transferred" [14]. The researchers claim that written documentation is generally not referred to when problems occur, as well as emphasising the short life span of software engineering knowledge. Kess and Haapasalo [15] advocate the use of project reviews to improve software quality. The results of a case study into a telecommunications organisation are disclosed, revealing the centrality of knowledge creation and sharing to improving the software development process. It is argued that project reviews enable both tacit and explicit knowledge to be managed effectively. Inspection metrics are portrayed as being integral to brainstorming sessions, which in turn deliver feedback to various phases in the software development process. Dingsøyr et al. [10] provide an insight into problems faced by small to medium organisations in addressing KM in SE. They consider postmortem reviews and experience reports as two approaches suitable for collecting software development knowledge. They conclude that lightweight postmortem reviews perhaps reveal more about software development practices, while experience reports are more suited to client relationships and interaction. Rus and Lindvall [20] declare organisations must facilitate both formal and informal knowledge sharing between software developers. They assert that KM complements existing approaches to software process improvement, rather than seeking to replace them. KM activities designed to support SE are grouped into three categories: purpose of outputs, scope of inputs and effort required to process inputs. A number of options for implementing and using KM systems for SE are advanced, such as expert identification, the creation of KM champions, document management and using predictive modeling to direct decision-making.

3. Research Methodology

The realist epistemology and ontology followed in this study support a retroductive research strategy. The research instrument used was a qualitative questionnaire. A total of twelve interviews were conducted at two Australian organisations in the IT services industry. A key determinant in the selection of

both organisations was their claim to apply KM principles in their work. Two projects from each organisation were reviewed, with three participants from each project interviewed. All participants were in software development roles in the projects examined.

3.1. Preparation of the Questionnaire

In this study, three KM existing models were used to establish a theoretical grounding for investigating the KM process for SE. The first model was the SECI model developed by Nonaka and Takeuchi [17], which has been acknowledged as an important contribution to understanding the creation of different types of knowledge. The second model was the 'Experience Factory' [3] which is synonymous with KM in SE, and has been implemented by both academics and practitioners with varying degrees of success. The third model was the American Productivity & Quality Centre and Arthur Andersen model for KM, which has formed the basis for benchmarking efforts in over 100 organisations globally [9]. After studying these well-known KM models, as well as existing literature, a list of KM process activities was developed. These process activities are: (1) knowledge creation, (2) knowledge acquisition, (3) knowledge identification, (4) knowledge adaptation, (5) knowledge organisation, (6) knowledge distribution and (7) knowledge application.

The questionnaire was based upon elements of existing KM models, as well as the KM activities suggested in this study as being components of the KM process for SE. The qualitative questionnaire incorporated three main sections: (1) background information about each participant and a nominated project, (2) activities performed in the KM process for SE and (3) enablers of the KM process for SE. In order to validate the questionnaire, a pilot study was conducted with individuals who were aware of the problem domain and the stated objectives of this study.

3.2. Case Studies and Interviews

Company A has a global workforce of over 130,000 people, with 6,700 working in Australia. It operates in over 60 countries worldwide. Approximately 35% work in software development roles, although its traditional focus has been managing outsourced IT infrastructure. The two projects (projects A1 and A2) studied both produced customer-specific products for external clients. In both projects, those involved from the client and Company A were located at the same site. Company B operates primarily in Australia and employs 2,500 people. It has clients in a diverse range of industries, including finance, government and retail. Approximately 40% work in software development roles. The two projects (projects B1 and B2) studied both produced customer-specific products for external clients. In both projects the project size was considered to be large. Both time and cost were priorities for both projects.

The questionnaire was administered to each participant in a private interview session, with only the researcher and the participant in attendance. The interviews were held at suitable times for participants, with the duration ranging 60-90 minutes. They were conducted in private meeting rooms at the premises of each organisation involved. Each participant was instructed to complete the questionnaire, and to provide additional comment/feedback verbally at any stage. The same interviewer conducted each interview, ensuring consistency in administering the research instrument. The interview sessions allowed each participant to clarify question phrasing, as well as to ensure participant responses addressed the research objectives of this study.

4. Results

This section presents the results from the qualitative questionnaire.

4.1. Current Practices for KM in SE

The first research objective of this research study was to investigate current KM practices in organisations engaged in software development. In focusing on current awareness of tools, techniques and organisational structures applied for KM in SE today a foundation for exploring the KM process for SE was established.

Company A: The majority of participants expected KM to lead to improvements in their work. Most participants confirmed that colleagues were a valuable source of knowledge, although the process for locating individuals with knowledge relied upon the scope of personal networks. The influence of standards was strong, with project documentation closely linked to methodologies promoted by the organisation. In project A1, participants were conscious of the apparent benefits associated with KM, despite the absence of a uniform process for applying KM in SE. Most participants were able to provide appropriate definitions for both knowledge and KM. Although personal networks were not formalised, participants engaged in regular discussions with each other during coffee breaks and team meetings, as well as through email. In project A2, KM was positioned as an

important component of the project plan. All participants were conversant with the structure of project repositories and group directories. However, participants encountered difficulty when asked to provide definitions for both knowledge and KM. As in project A1, a KM process model for SE work had not been formalised.

Company B: As in Company A, KM was considered to be an important component of the work performed by software developers. The influence of standards on KM was also visible in the two projects studied. However, the absence of KM systems and the limited search facilities for archives and repositories indicates the relative immaturity of the KM process for SE in Company B. In project B1, regular feedback was delivered to participants after reaching each milestone. The majority of participants were able to provide appropriate definitions for both knowledge and KM. The location of experts depended heavily on the extent of personal networks. The level of discussion and networking among project team members was also limited. In project B2, some participants displayed confusion when asked to define both knowledge and KM. Most participants were able to identify and resolve problems using their existing knowledge, although searching facilities were restricted. All participants were able to adapt existing knowledge to produce innovative solutions to problems. In addition, sharing knowledge with others was undertaken with a view to enhance the capabilities of the project team, and to ultimately produce a quality product.

4.2. KM Activities for SE

The second research objective of this study focused upon activities performed in the KM process for SE. Each participant was asked whether each of these activities was performed explicitly, implicitly or not at all in each project studied. Furthermore, participants were asked to denote the percentage of total KM effort for a project assigned to each activity (Figure 1).

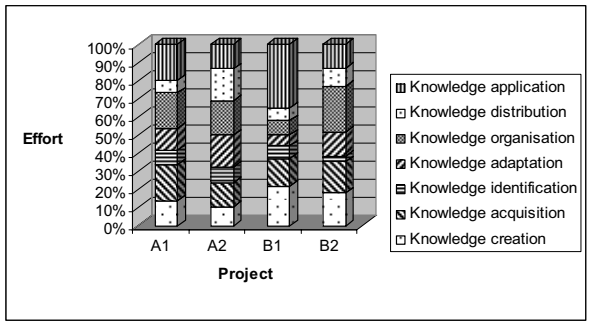

Figure 1. Distribution of effort for all projects

Company A: In project A1, the majority of participants understood knowledge identification and knowledge organisation to be performed explicitly. Both knowledge creation and knowledge application were performed implicitly. The remaining activities were performed both implicitly and explicitly. In terms of the total amount of effort allocated to each activity, both knowledge organisation (20%) and knowledge application (20%) required the most effort. However, in project A2, most activities in the proposed KM process model were performed explicitly. Knowledge adaptation was performed implicitly by all participants, while knowledge creation was performed both implicitly and explicitly. In terms of the total amount of effort allocated to each activity, knowledge organisation (18%) and knowledge distribution (18%) required the most effort.

Company B: In project B1, knowledge creation, knowledge acquisition and knowledge application were performed explicitly. The remaining activities were performed implicitly. In relation to the total amount of effort allocated to each KM activity, knowledge application (35%) required the most amount of effort. However, in project B2, knowledge organisation and knowledge distribution were performed explicitly. The remaining activities were performed implicitly. This implies that the visibility of the KM process used for SE in project B2 was low, with KM process activities being embedded within the context of the software development lifecycle followed in this project. In relation to the total amount of effort assigned to each KM activity, knowledge organisation (26%) required the most amount of effort.

4.3. KM Process Models for SE

The third research objective was to establish high-level descriptive models of the KM process for SE. The results of this study show that KM activities were embedded within the context of the software development lifecycles adhered to by each organisation. Despite the problem domain of KM in SE still being in its infancy, participants were able to associate KM activities proposed in this study with stages in the lifecycles used by each project. This signals that positive efforts have been made by software developers to incorporate KM process activities into their normal work practices. Although high-level descriptive models of the KM process were created for each project, because of the variance in which KM activities were performed between projects, a single high-level descriptive model of the KM process for SE could not be constructed. Further details

on these process models can be found in Ward and Aurum [21].

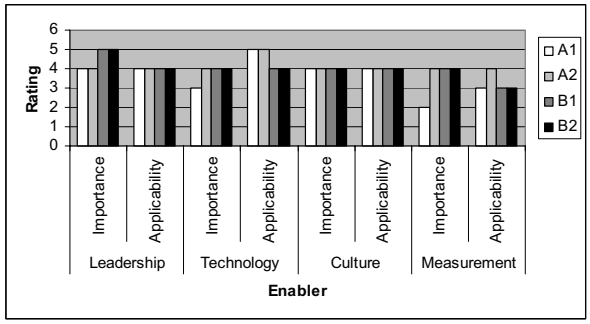

Figure 2. Four enablers in all projects

4.4. Enablers of the KM Process for SE

The fourth research objective was to evaluate the impact of enablers such as leadership, culture, technology and measurement on the KM process for SE. Each participant was asked questions pertaining to leadership, technology, culture and measurement in terms of the KM process for SE. The *importance* and *applicability* of each enabler to the KM process for SE was also rated by participants using a Likert scale. This rating was used to summarise how each enabler was viewed by participants, as well as solidifying links with activities in the KM process for SE (Figure 2).

Company A: Leadership emerged as having the most significant impact upon KM in SE. It was assigned an average rating of 4 for both its importance and applicability to the KM process for SE. Although half the participants assigned a rating of 2 or 3 for the importance of technology, a high rating for its applicability was consistently recorded. For culture, a similar variance was displayed, with half the participants assigning a rating of 3 for both its importance and applicability. The ratings assigned for measurement suggest that it was the least appreciated of the four enablers, in terms of both its importance and applicability to the KM process for SE.

Company B: Leadership, technology and culture emerged as significant enablers of the KM process for SE. In terms of importance, all three consistently received high ratings. However, participants were divided about the applicability of culture. Measurement had the lowest ratings for applicability, despite every participant rating it highly in terms of its importance to the KM process for SE. This dichotomy may be explained by the difficulty many participants expressed when asked to identify appropriate measures that could be used to determine the knowledge they possess. The lower ratings for applicability may also be a product of inappropriate measurement strategies adopted by management, resulting in cynicism towards ascertaining job performance based on these measures.

5. Discussion

This section presents discussion of findings using the supporting arguments from structured interviews with software developers.

5.1. Current Practices for KM in SE

This section focuses on the current practice for KM in SE based on four elements: types of knowledge, motivation, knowledge sources, and KM systems.

Types of knowledge: In both companies, the type of knowledge applied for software development in the projects examined was primarily tacit. Success stories were not frequently shared between project team members. However, a number of structures had been established for storing explicit knowledge, such as group directories, archives and repositories. Despite the accessibility of explicit knowledge, the third participant from project A1 highlighted the difficulty in converting tacit knowledge to explicit knowledge: *"To be honest, I'm not sure how you'd formally put it down in a way that you could reference it."* The third participant from project B2 commented that the particular system used for this project mandated individuals with specialist expertise: *"Unless you know that certain programs and files relate to each other, you're never going to know."*

Motivation: In Company A, the majority of participants believed career progression was associated with the ability to continually move between different projects. The second participant from project A2 asserted: *"Whenever I was able to become redundant, I could find a better job."* In both companies, most participants claimed their primary motivation for sharing knowledge with other team members was the desire for everyone to be able to perform their duties at a similar level. In Company B, the importance of obtaining appropriate KM tools was mentioned by some participants, as well as the explicit recognition of KM activities in project schedules. The third participant from project B2 believed these two factors would increase motivation to engage in KM activities: *"Yeah, then it would definitely happen. I don't think rewards…the rewards are it would make future projects easier."*

Knowledge sources: In Company A, the majority of participants from project A2 preferred a 'Learn by Doing' approach to acquiring knowledge, rather than attending formal training programs. The knowledge gained from participating in formal training programs was considered to be irrelevant unless it could be applied immediately. Furthermore, both the time and cost of such programs meant they were offered infrequently to participants. Finding subject-matter experts was an informal process, with an onus being placed upon participants and their managers to leverage personal networks. The third participant from project A1 maintained that colleagues were the most useful source of knowledge, although questioned their ability to organise and distribute knowledge with others: *"But, colleagues…I don't think you can ever go past them."* In Company B, personal networks were seen as the primary mechanism for transferring knowledge between project team members. The second participant from project B1 specified the role of personal networks in supporting KM in SE: *"Yeah, I mean, it's probably the primary way, when you think about it. Just because that's the first place you go to, another team member."* The use of third-party knowledge was common, with the main sources being the Internet and magazines. Most participants were comfortable using this knowledge, although they appreciated that some modifications may be necessary. Formal training programs were scheduled infrequently, with most problems being overcome after using a "Learn by Doing" approach. There was also some confusion as to whether project repositories and archives were accessible organisation-wide.

KM systems: In Company A, all participants were aware of repositories and archives containing knowledge from earlier projects. New employees were introduced to the main group directories as part of their induction programs, underlining the importance assigned to maintaining the currency and relevance of knowledge bases. Company A had also tried to foster online communities, to assist employees in communicating with others sharing the same interests. The first participant from project A2 described the process for submitting a question about the preparation of test scripts to a global KM community maintained by Company A: *"…we had some templates, but then we decided to post a message to the GSMS community. In less than an hour, we had around 20-30 responses."* In Company B, the responses of participants from Company B reveal that KM systems were not made available. Some participants expressed frustration with the limited avenues for communicating feedback. There was optimism about the effect a KM system could have on knowledge re-use, although it remained largely untracked. In project B1, a software development framework developed for a similar project was re-used. It can be argued that the use of a KM system would eliminate the risk of re-using knowledge without accounting for the idiosyncrasies of each project. The first participant from project B1 stated: *"What we do now is create a framework for what we did from the last project. We're using, basically, the same framework now."*

5.2. KM Process Activities for SE

This section focuses on the application of seven KM processes in two companies.

Knowledge creation: Knowledge creation was performed both implicitly and explicitly across all projects examined. All participants recognised it being performed in their software development work. A medium amount of effort was allocated to this activity, ranging from 10% to 25%. Team meetings were affirmed as crucial opportunities for team members to discuss new ideas, to offer advice as well as to commit to documenting knowledge and experience. The third participant from project A1 noted that project reviews did not always result in a balanced assessment of positive and negative outcomes from a project: *"It would just be a case of 'This screwed up. What did we do wrong? Let's make sure we don't do it again."*

Knowledge acquisition: Knowledge acquisition was performed both implicitly and explicitly across all projects examined. A medium amount of effort was assigned to this activity, ranging between 10% and 20%. Team meetings, feedback about project status and observation of problem areas was ordinarily encouraged. In addition, colleagues were seen as valuable sources of knowledge. This may imply that the tacit knowledge held by individuals facilitated the transfer and acquisition of project-specific knowledge. At Company A, code reviews were seen as even more useful, since more specific knowledge was generally produced. The first participant from project A2 stated: *"Well, of course, yeah…at team meetings as well. But, regular code reviews were generally the best."*

Knowledge identification: Knowledge identification was performed both implicitly and explicitly across all projects examined. In project B1, this activity was performed implicitly by all participants, whereas in Company A some participants had difficulty envisioning this activity being performed in normal project work. A small amount of effort was assigned to this activity, ranging between 0% and 10%. The third participant from project A1, when asked about

identifying current software development problems using knowledge gained from previous work, stated: *"Mostly, it's just stuff I've stored in my head. I'm pretty hopeless with documenting things like that."* At Company B, most participants were comfortable with re-using knowledge from earlier projects to identify problems, although this knowledge was often tacit.

Knowledge adaptation: Knowledge adaptation was performed both implicitly and explicitly across all projects examined. A common view was that updating a knowledge base was an onerous task, and subsequently given a low priority in projects. A key inhibitor was time, exacerbated by constant movement between projects and geographic locations. A small amount of effort was assigned to this activity, ranging between 5% and 20%. The majority of participants from both companies preferred generic knowledge, citing its applicability in multiple situations. This preference may arise from the variety of problems faced by software developers working for an IT services organisation. The third participant from project A2 asserted that project-specific knowledge restricted the opportunities of software developers in the future: *"I would say it is very limited knowledge that isn't useful to…anything in the future."*

Knowledge organisation: Knowledge organisation was performed both implicitly and explicitly across all projects examined. A medium amount of effort was assigned to this activity, ranging between 5% and 30%. Many participants felt remote access was either too slow or not possible. The constant travel of consultants working in a technology services organisation was identified as a reason for the perceived difficulty in accessing archives and repositories. At Company A, directory structures were tied closely to the use of particular methodologies. Despite this, the first participant from project A1 was critical of the software development methodologies being employed: *"The directory structure is how you would use the document, not what you use."* At Company B, many participants were unsure about the existence of archives and repositories, while determining the contents of certain documents often required project-specific knowledge. The second participant from project B1 stated: *"…as far as I'm aware of, there's no central repositories with any kind of searching facilities."*

Knowledge distribution: Knowledge distribution was performed both implicitly and explicitly across all projects examined. The majority of participants assigned less than 10% effort for this activity. Most participants were able to identify multiple sources of knowledge about policies and procedures governing software development in Company A. Some popular sources included the Internet, magazines as well as colleagues. The primary motivator for sharing knowledge was overwhelmingly career progression. The second participant from project A1 commented: *"[But] the not altruistic answer is if they know it, I don't have to do it."* Another motivator that emerged was to mitigate the risks associated with losing tacit knowledge when individuals leave an organisation. At Company B, participants revealed more altruistic intentions when explaining their reasons for sharing knowledge. The first participant from project B2 alleged that sharing knowledge was linked to quality: *"Sharing means others can solve problems faster and are less likely to be frustrated, resulting in a more efficient and happy working environment."*

Knowledge application: Knowledge application was an activity performed both implicitly and explicitly across all projects examined. A medium amount of effort was assigned for this activity, ranging between 10% and 35%. All participants were comfortable re-applying their existing software development knowledge. The level of satisfaction with third-party knowledge was generally high, with participants willing to conduct extensive searches until locating a knowledge item suitable for their purposes. Most participants were able to conceive benefits associated with a system to track knowledge re-use by project team members. However, in both organisations no system currently exists for this purpose. In describing some of the potential benefits of such a system, the second participant from project A1 stated: *"They can see a gap between the knowledge they know about and the knowledge they ought to know about."*

5.3. KM Process Models for SE

In both companies, there was a medium level of KM process awareness, with a number of KM systems made available for participants to use. It can be argued that in both companies software developers had a limited appreciation for phases other than those concerning implementation. This may have limited their ability to conceptualise some KM activities being performed explicitly.

The third participant from project A1 conferred a sense of how the KM process was interwoven with the particular software development lifecycle followed by each project in Company A: *"It's one of those sorts of things you do, without consciously going about it. Even the stuff you do explicitly is still just part of that cycle."* The third participant from project B2 reaffirmed his awareness of the KM activities presented in this study being performed in this project:

"Oh, yeah. It's just varying degrees of how well and how much of it was done, really."

5.4. Enablers of the KM Process for SE

This section discusses leadership, technology, culture and measurement as enablers of the KM process for SE.

Leadership: In Company A, a culture of implicit rewards for sharing knowledge was demonstrated, with the first participant from project A1 revealing that the quantity of contributions was a key determinant in gaining recognition: *"If you publish a lot of things about knowledge, you tend to be well known."* On the other hand, in Company B, the responses of participants denote that leaders had a significant influence upon the KM process applied for software development. It was felt a link between KM and improved business performance had been promoted by leaders. Nevertheless, many participants believed it was ultimately their responsibility to ensure the knowledge they gained from project work was preserved and made accessible to others. The first participant from project B1 asserted: *"If you think of knowledge as everything, it's basically everyone's responsibility."*

In both companies most participants could not identify specific roles that were responsible for managing knowledge. It was assumed that project team members and the project managers were responsible for managing knowledge relevant to them. Most participants were unable to specify a KM 'champion' for their organisation, either at project-level or at a higher level.

Technology: A number of organisation-specific KM tools/systems were regularly promoted in Company A. Most participants sensed that technology was important to the KM process, despite it not being considered as applicable. KM systems were perceived to be unwieldy and ineffective at delivering knowledge suitable for resolving specific problems. The second participant from project A1 indicated that technology makes sharing tacit knowledge with others problematic: *"If it's a rule of thumb kind of...something that's ephemeral, that's hard to document…then it's really 'Learn by doing', or pass it on verbally."*

The first participant from project A1 affirmed a preference for the Internet over KM systems maintained by Company A: *"What you want is 'How to do this', 'How to do that'. Those are very rare."* This preference may be driven by the plethora of Internet search engines that deliver an enormous amount of information to users. This comment also conveys the difficulty in creating a KM system that delivers content that is either general or specific, in a readily accessible format.

However, in company B, all participants expressed their disappointment with the absence of specific KM systems in their organisation and the inaccessibility of project archives or repositories. The second participant from project B1 reinforced the role technology is required to play in software development projects: *"Well, it's probably…when you look at the way we work, it's probably the only way."*

Culture: In Company A, participants produced mixed responses. The first participant from project A2 believed the link between knowledge and power was detrimental to quality, increasing risk as a by-product of some individuals becoming irreplaceable: *"They would be the sole point of knowledge. And, of course, the sole point of failure if something happens."*

Most participants regarded annual performance reviews as ineffective measurement tools that failed to institute a beneficial dialogue for knowledge sharing between manager and developers. The feedback delivered was considered to be too general, focusing on personality rather than performance in specific projects. A preference was exhibited for feedback to be delivered to software developers either during, or immediately after a project. The second participant from project A2 noted: *"I guess it's better to do it straight after, because you remember what you did for the past six/seven months."* The third participant from project A1 expressed concern about the KM culture that management was attempting to cultivate: *"And, forcing them down throats and forcing people to submit stuff to them is really the wrong way to go about it, I think."* In contrast, Company B had arranged information sessions, where employees possessing skills in a particular area would give a presentation on a topic of interest to others in the organisation. The level of feedback was an area that most participants felt needed improvement. While the annual review process had been well established in Company B, participants displayed a strong preference for feedback to be delivered to them during a project. There were no explicit reward systems for those who effectively managed their own knowledge, or the knowledge of others. Nonetheless, the second participant from project B1 asserted that implicit rewards were offered by management: *"[So] if management realises that you have been contributing a lot of knowledge to others, then quietly they give you a bonus."*

Measurement: The responses of participants reveal that Company A has invested limited resources in

developing appropriate measures for evaluating the impact of KM in SE. Most participants also encountered difficulty when asked to advance suitable measures for evaluating the knowledge of individuals. The third participant from project A1 provided further support for this argument: *"I'd say it would be nice, but it's like a lot of intangibles, near impossible to measure. How do you measure it?"* Yet, the third participant from project A2 believed that measurement for KM in SE was tied to annual performance reviews, as well as the content of online CVs: *"Yeah, they are updated regularly. So, I guess, yeah…I think they are more than appropriate, more than that I'll just scream."*

In Company B, all participants encountered difficulty when asked to examine the relationship between measurement and KM. The second participant from project B1 believed measuring knowledge was problematic, possibly because tacit knowledge cannot be evaluated using traditional quantitative measures: *"It's hard to measure. It's hard to measure apart from a few sort of things."* Mixed responses were recorded when participants were asked whether their true value to their organisation could be measured based upon the amount of knowledge they possessed. Some participants professed that other qualities in addition to the knowledge they possessed contributed to their true value. The first participant from project B1 commented: *"You become a subject matter expert, I guess, people will know…you don't have to advertise, people will come to you to ask you about it."*

6. Validity Threats

Four different types of threats should be addressed in this study [22].

Internal Validity: This threat is related to issues that may affect the causal relationship between treatment and outcome. While all participants in this study were software developers, the diversity arising from educational backgrounds and industry experience was documented. The questionnaire used was developed with close reference to existing models and literature relating to KM in SE, and was piloted multiple times. It was also administered in an interview situation, with some lasting up to 90 minutes. Some participants may have provided shorter responses as more time elapsed. Other participants may have attained a greater appreciation of the intended purpose of each section, hence enhancing their responses.

External Validity: This threat is concerned with the ability to generalise the findings beyond the actual study. The participants selected may not adequately reflect the diversity of opinion present in the population examined. In this study, software developers were targeted, given their integral role within SE and their appreciation for process-orientation. Thus, it was felt that this sample would convey a realistic perspective of the KM process applied for SE today. Both sample size and timing also influence the external validity of a study. The small sample size used may indicate that any conclusions drawn from this study are not generalisable outside the context of the IT services industry in Australia. The nature of this study is predominantly exploratory, with an emphasis upon describing the KM process used in SE practice in the period 2002-2003. It is expected that future research will reveal more advanced thinking about the KM process in industry, hence altering the generalisations that can be made.

Construct Validity: This threat is concerned with issues related to the design of the study and social threats. This study was carefully developed, with the design being piloted and a detailed analysis of constructs such as knowledge and KM undertaken. The three models underpinning the research were also explained, establishing a connection with the objectives of this study. In addition, multiple case studies were completed to present diverse perspectives of KM in SE. The researcher conducted a number of interviews in two separate organisations, involving participants from different projects. Two social threats relevant to this study are hypothesis guessing and experimenter expectancies. Each participant was only given a copy of the questionnaire during each interview, to reduce the possibility of answers being modified to suit perceived hypotheses. The researcher was also mindful of the need to prevent conscious or unconscious expectations from altering the collection or analysis of results.

Conclusion Validity: This threat is concerned with issues that affect the ability to draw the correct conclusions about the relationship between treatment and outcome. Both question wording as well as the construction of a research instrument can influence the conclusions drawn from a study. From the pilot study, phrasing of questionnaire items was improved significantly. The questionnaire was divided into three main sections, with numerous subheadings outlining its logical structure to assist participants. The reliability of treatment implementation is also a significant notion to consider. In this study, care was taken to ensure that verbal questions asked in interviews were asked consistently across all interviews conducted. Other considerations are random irrelevancies in

experimental settings and random heterogeneity of subjects. A standard environment was maintained for all interviews conducted, occurring in meeting rooms at the premises of each organisation. All participants were software developers, therefore limiting random heterogeneity in the group.

7. Conclusion

This study has contributed a description of the KM process for SE, based upon two case studies conducted in an Australian context. This study has not addressed whether the KM process for SE is analogous to processes used in other areas or fields. A number of activities suggested as being components of the KM process for SE have been examined. The impact of leadership, technology, culture and measurement on the KM process for SE was also assessed.

The results of the study indicate that the tools, techniques and methodologies currently employed for software development are inadequate to address KM effectively. Despite the absence of a uniform model of the KM process in either organisation, participants were able to recognise KM activities being performed in their projects. Leadership also emerged as the most significant enabler of the KM process for SE. Future work may examine the KM process for SE in other industries and contexts, as well as the perspectives of other roles associated with software development.

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