Knowledge Construction in the Software Industry — Postprint of Research on Sri Lankan Software Companies

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Abstract

[Purpose / Significance] Software organizations rely on knowledgeable software developers. Software developers must accumulate knowledge of new technologies and domains, learn organizational policies, conduct practical activities, possess cultural consensus, and actively participate in software development activities. The uniqueness and inherent nature of software development activities imply that employing effective knowledge management activities to manage software knowledge within software organizations is crucial. In the software development environment, strengthening knowledge creation and sharing among software engineers is a formidable task.

[Method / Process] This study employs a mixed-methods approach combining quantitative and qualitative methods to analyze software engineers' perceptions of knowledge management practices utilized by their organizations. Semi-structured interviews and questionnaire surveys were conducted separately at three software companies in Sri Lanka. The survey results indicate that these three software companies recognize the importance of knowledge sharing and the necessity of organizational learning, which serves as a strategic tool for gaining competitive advantage and solidifying organizational success.

[Results / Conclusion] The research findings confirm that information and communication technology has an impact on knowledge management practices and subsequently on the expected intervention in innovation. Additionally, the study analyzes various knowledge management tools and technologies used by the three participating software companies and identifies barriers to implementing knowledge management activities. This study also proposes a new approach for organizational managers to enhance organizational efficiency through knowledge management activities.

Full Text

Preamble

Knowledge Construction in Software Industries—A Study from Sri Lankan Industrial Perspective

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Abstract

[**Purpose/Significance**] Software organizations depend on knowledgeable software developers who must continuously accumulate new technologies and domain knowledge, learn organizational policies, engage in practical activities, develop cultural consensus, and actively participate in software development. The unique and inherent nature of software development activities signifies the critical importance of employing effective knowledge management (KM) activities within software organizations to manage software knowledge. Enhancing knowledge creation and sharing among software engineers represents a formidable challenge in software development environments.

[**Method/Process**] This study employs a mixed-methods approach combining quantitative and qualitative analyses to examine software engineers' perceptions of knowledge management practices utilized in their organizations. Semi-structured interviews and questionnaire surveys were conducted across three software companies in Sri Lanka. The findings indicate that these companies recognize the importance of knowledge sharing and the necessity of organizational learning as strategic tools for gaining competitive advantage and ensuring organizational success.

[**Result/Conclusion**] The results confirm the influence of information and communication technologies on knowledge management practices and their subsequent expected implications for organizational innovation. Additionally, the study analyzes various knowledge management tools and techniques employed by the three participating companies, identifies barriers to implementing knowledge management activities, and proposes a new perspective for organizational managers to enhance organizational efficiency through knowledge management initiatives.

Keywords: software engineering, knowledge management, KM practice, tacit knowledge, organizational learning
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1 Introduction

Software development is a knowledge-intensive collaborative activity whose success depends on developers' knowledge and experience. Software developers must accumulate new technologies and domain knowledge, learn organizational policies, engage in practical activities, achieve cultural consensus, and actively participate in software development. Consequently, substantial knowledge can be captured and stored for future application. Knowledge management practices are therefore applicable to knowledge management in software engineering. A primary objective of knowledge management is to manage knowledge more efficiently, ensuring that the right knowledge reaches the right people in the right form at the right time.

This research investigates three software companies in Sri Lanka that have applied knowledge management concepts and tools to varying degrees for managing organizational knowledge. The investigation aims to understand their practices, dissatisfaction and expectations, motivations, and obstacles to implementing knowledge management practices. Furthermore, the study identifies hidden problems and barriers during knowledge management implementation, reveals their root causes, and proposes corresponding recommendations, solutions, and future research directions. These experiences offer valuable insights for knowledge management and creativity support in the software industry.

The majority of statistical data presented herein result from comprehensive analysis of questionnaire data using SPSS (Statistical Package for the Social Sciences). Descriptive statistics, particularly those in tables, facilitate detailed analysis of surveyed software developers' characteristics and responses.

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2.1 Knowledge Management in Organizations

Distinguishing between information and knowledge is crucial. Data are discrete elements that form the foundation for creating information. When meaning is assigned to data, it becomes information with a meaningful structure. Knowledge is defined within the information scope and results from people's perception, learning, and reasoning. Knowledge enables enterprises to make decisions and take effective measures to achieve business objectives. Some literature describes the functional relationship among data, information, and knowledge using an iterative hierarchical cycle structure. Additionally, a survey study from a Japanese research university indicates that the transformation cycle among data, information, and knowledge follows a spiral pattern.

According to M. Polanyi's definition, knowledge can be divided into two types: tacit knowledge and explicit knowledge. Tacit knowledge refers to intuitive, inarticulable, difficult-to-express, or even inexpressible knowledge. It is acquired by individuals through internal cognition such as experience, reflection, internal sublimation, or personal talent, and therefore cannot be managed and disseminated like explicit knowledge. Explicit knowledge can be clearly expressed and stored in documents, folders, databases, emails, and software code, making its handling more objective, rational, and technical.

Universities and research institutions are typically the birthplaces of academic knowledge. A. P. Wierzbicki and Y. Nakamori proposed the EDIS spiral theory (Enlightenment-Debate-Immersion-Selection) to describe the universal knowledge creation process in academia.

2.2 Knowledge Management in Software Engineering

Numerous studies have examined knowledge management's contribution to software engineering, including case studies, experiments, and survey analyses across different domains. Nonaka and Takeuchi's *The Knowledge-Creating Company* illustrates how Japanese companies excel through their knowledge creation capabilities. Bjørnson proposed solutions for knowledge management challenges faced by small and medium-sized enterprises in software engineering, arguing that post-mortem reviews and experience summaries are particularly suitable for collecting software development knowledge, especially lightweight experience reports.

Information and communication technology (ICT) plays a significant supportive role in enterprise knowledge management implementation. A. Aurum's investigation of knowledge management practices in two Australian software companies revealed that leadership, technology, culture, and measurement methods have become enablers of knowledge management processes in Australian software firms. Teamwork among software developers generates substantial knowledge, highlighting the significance of effective knowledge sharing among individuals. Qualitative empirical studies have analyzed how software newcomers acquire knowledge and the factors affecting knowledge transfer in small software industries.

R. Ruggles presents a contrasting perspective on knowledge management in software industries. His survey of 431 software industry managers in the US and Europe found that the software industry lacks confidence in knowledge transfer and generation. S. Komi-Sirvio studied requirements-based knowledge management, conducting interviews with employees of a software development company. Preliminary results showed that recommended methods such as "experience databases" and "data transfer days" were ineffective. K. C. Desouza proposed that establishing a knowledge management system for software process management would increase product maturity, enabling higher quality and more profitable product development.

This study adopts knowledge identification, acquisition, creation, sharing, storage, and application as the primary knowledge management activities.

2.3 Knowledge Construction Methods

The primary model for knowledge integration is the "i-system" proposed by Y. Nakamori, illustrated in Figure 1 [Figure 1: see original paper]. This study examines the current state of knowledge management practices in three software companies. In this framework, new knowledge is constructed through three subsystems: Intelligence (scientific front), Involvement (social front), and Imagination (cognitive front). The starting node is Intervention (where problems are presented as actions), and the final node is Integration (where new knowledge is constructed).

The knowledge construction system theory proposed by Y. Nakamori applies this perspective to explain how necessary knowledge should be constructed to solve today's complex problems. "Intervention" involves taking action before problems are addressed. This study explores knowledge management practices in Sri Lankan software companies through three subsystems: the scientific front—"Intelligence," collecting data and information through semi-structured interviews with management; the social front—"Involvement," gathering data through semi-structured interviews with senior software engineers experienced in knowledge management practices about their activities, dissatisfaction, expectations, and ideas; and the cognitive front—"Imagination," creating one's own knowledge based on new or existing knowledge. The final stage, "Integration," represents the systematic synthesis of the creative process, encompassing research outcomes (content, results, and findings), survey results (successes or failures, new problems), and new research plans (next project phases).

This framework is a procedural knowledge construction method that proposes how to build necessary knowledge to solve complex problems through the interaction of explicit and tacit knowledge. Y. Nakamori applied this model to construct knowledge applications such as the Biomass City Project, a regional environmental protection activity in a Japanese city. The newly constructed knowledge includes hidden problems, barriers, and root causes in knowledge management practices, which will also aid decision-making.

3 Survey Overview

This study primarily explores knowledge management practices in the software industry. Information should be collected from different personnel engaged in knowledge management practices. First, information is gathered from company management to understand their motivations and barriers to promoting knowledge management practices. Second, data is collected from software developers with knowledge management experience to understand their experiences, dissatisfaction, expectations, and perceptions. Finally, opinions from all software developers across the three companies are obtained to understand their views, concerns, difficulties, and obstacles regarding knowledge management activities. A mixed-methods approach is employed for data collection, as C. Teddlie and A. Tashakkori argue that mixed methods provide more opportunities for answering research questions and better evaluating the credibility of research results and their inferences.

The questionnaire comprises eight sections developed in English based on literature review and expert opinions from industry researchers. The first section covers demographic information (work experience, job description, competencies). Subsequent sections address knowledge identification, acquisition, creation, sharing, storage, application, knowledge management tools, and knowledge management barriers. A five-point Likert scale is used to collect respondents' attitudes: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1). The decision criterion for this study is a mean value of 3.

The researcher obtained a list of Sri Lankan IT companies by contacting SLASSCOM (Sri Lanka Association of Software and Service Companies). Based on the 2014 SLASSCOM annual report, the researcher communicated with companies implementing knowledge management practices. Seven companies responded to the research request, and after carefully examining their profiles, three were selected considering company size, industry reputation, employee experience, and project volume. All three companies have substantial employee bases (see Table 1), excellent reputations, experienced staff, and numerous software projects. Additionally, these companies have invested significant time and resources in improving knowledge management practices. Following research ethics, the three companies are labeled A, B, and C. Company A is a global IT firm providing consulting, technology, and outsourcing services, and is a leading software supplier for banking, financial services, insurance, telecommunications, technology, and media industries. Company B is a globally recognized leader in developing and delivering ERP (Enterprise Resource Planning) software. Company C is a provider of applications and services for telecommunications, finance, and enterprise markets, specializing in human resource applications and enterprise wireless mobile applications. Further analysis of these companies appears in the findings section (see 4.1).

A pilot study approach (module-oriented and project-oriented) was adopted for these companies (10 participants per company), using in-depth interviews and questionnaires to establish and validate issues for large-scale surveys and semi-structured interviews. After successful reliability and validity analysis, the final version of the method was developed, as shown in Table 2 .

The online survey collected 459 responses, including 333 male and 126 female respondents (see Table 1). SPSS 2.0's missing value analysis helped address issues caused by incomplete responses. This study employed missing value imputation techniques proposed in reference [22] for mean substitution of missing values.

An outlier is an observation that deviates so significantly from other observations as to arouse suspicion that it was generated by a different mechanism. True outliers differ substantially from other observations and violate reasonable relationships among variables. Data mining, capable of handling different data types and discovering non-ignorable, hidden, and interesting patterns, can be introduced for this analysis. Outlier detection is a fundamental issue in data mining [23]. This study uses cluster analysis-based outlier detection to identify and remove anomalous objects from the data.

4.1 Profiles and Statistics

It is necessary to determine the demographic profiles and statistical characteristics of survey participants, including respondent types, response rates per company, educational background, and industry work experience.

4.1.1 Respondent Profiles

The distribution of respondents' positions in this survey is shown in Figure 2 [Figure 2: see original paper]. Semi-structured interviews were divided into "management" and "senior software engineer" perspectives. Interviews with senior software engineers and company management helped deepen understanding of research questions and collect information. A total of 12 respondents across the three companies were interviewed, with two respondents per perspective per company, yielding qualitative data on various aspects of knowledge management practices. This approach facilitated obtaining more detailed company information and served as a means for respondents to answer follow-up questions in depth.

4.1.2 Companies

The researcher recorded respondents' workplaces through the questionnaire. The number of respondents was sufficient to ensure participation from all types of personnel. The distribution of respondents across companies is shown in Figure 3 [Figure 3: see original paper]. To protect company privacy, company names are replaced with A, B, and C.

4.1.3 Software Development Experience

Figure 4 [Figure 4: see original paper] shows the distribution of respondents' years of experience in software companies. The figure reveals that less experienced respondents showed higher participation rates. Only 19.39% of respondents had more than five years of experience, while approximately 16.99% had three to five years of experience. Since participants' responses relate to work experience, this helps obtain valuable data from a broader population.

4.1.4 Highest Education Level

The researcher recorded respondents' educational backgrounds through the questionnaire. The distribution of highest education levels is shown in Figure 5 [Figure 5: see original paper]. The results indicate that 69.28% and 27.02% of respondents hold bachelor's and master's degrees, respectively, while 14% have high school education and only 4% hold doctoral degrees.

4.2.1 Familiarity with Knowledge Management Concepts and Tools

Our primary objective is to understand the current state of knowledge management practices, including the tools, techniques, and organizational structures currently employed (see Table 3). Company A's software developers demonstrate relatively unfavorable levels of awareness, experience, and familiarity with knowledge management practices. In contrast, Company B's software developers show greater awareness, richer experience, and higher familiarity, with average levels in a favorable state.

4.3 Experience-Based Learning

Knowledge is formed through previous projects and development experiences in a process called knowledge transfer. Approximately 79.74% of respondents indicated that past development experience enhanced their learning capabilities, as shown in Figure 6 [Figure 6: see original paper]. The results suggest that software developers should be provided with more technical support to better create, acquire, and share knowledge.

Effective software development relies on knowledge collaboration and software engineers' creativity. Software engineering knowledge is dispersed across different domain resources, including explicit knowledge and knowledge stored in human brains. Therefore, teamwork is key to effective organizational learning. Teamwork provides software developers with opportunities to learn from others, collaborate, share information, and discuss and generate new ideas together. However, the importance of teamwork was also questioned by respondents (see Table 4). The survey found that Company B's respondents were more willing to share information with others or seek help to solve problems during software development activities, while Company C's software developers showed little interest in these situations, and Company A's results fell in between. These findings underscore the importance of teamwork.

4.5 Utilization of Organizational Knowledge

Organizational knowledge refers to the collective knowledge within an organization that software developers acquire from experiences and projects. This knowledge is "owned" by the organization and can be collected and organized, remaining within the organization even when employees leave. As previously mentioned, explicit knowledge can be easily organized and preserved, while tacit knowledge is difficult to organize and even more challenging to identify.

The survey asked respondents to answer questions regarding their satisfaction with organizational knowledge utilization (see Table 5). Clearly, software developers prefer to draw on previous experiences and utilize existing project documents, but knowledge stored solely in repositories is insufficient and must be seriously considered in the future.

4.6 Gender-Based Differences

Table 6 shows gender-based comparisons across various dimensions considered in this study. The mean values for both genders are nearly equal across all dimensions, indicating that gender differences have minimal impact on the research results.

4.7 Correlation Analysis

Correlation analysis was conducted to test relationships among knowledge dimensions. Table 7 shows that knowledge storage is significantly correlated with all dimensions except knowledge sharing (correlation coefficient of only 0.05), with a particularly strong correlation coefficient of 0.75 with knowledge application. Furthermore, the results clearly indicate that the knowledge sharing dimension shows little correlation with other dimensions. The researcher speculates that this may be related to individual, organizational, or technical issues.

4.8 Managing Software Knowledge

Figure 7 [Figure 7: see original paper] presents the overall average values of knowledge dimensions across the three companies. Company B demonstrates stronger capabilities in knowledge acquisition, creation, and storage. Company C should explore methods for deploying knowledge repositories, potentially using powerful search engines and knowledge management systems to assist its software developers. Additionally, Company B's knowledge sharing average of 3.04 is lower than its knowledge creation average (4.40) and knowledge acquisition average (4.00). The researcher analyzes that the low average values for the knowledge sharing dimension across all three companies may result from inadequate utilization of existing robust access methods, incomplete ICT infrastructure, and organizational culture influences. Organizational culture affects developers' willingness and behavior, either encouraging or hindering knowledge sharing activities.

4.9 Knowledge Management Tools

Knowledge management tools play a crucial role in coordinating software developers' activities during project development. Broadly speaking, knowledge management tools are technologies that accelerate knowledge generation, organization, and transformation. Like other tools, they are designed to reduce workload and allow users to apply them effectively to the most suitable tasks. Notably, not all knowledge tools mentioned in this study are computer-based.

The results (see Figure 8 and Table 12 in Appendix A) confirm that the most commonly used knowledge management tool is the portal website, followed by search and retrieval agents and local area networks. Online forums are also frequently used computer-based knowledge management tools. Companies rarely use instant messaging, Wikipedia, blogs, and social media due to concerns about project data security, fraud prevention, identity theft, and privacy leakage. Additionally, groupware, knowledge management systems, data warehouses, and data mining are used minimally or not at all, as ICT infrastructure for knowledge management systems and data warehouses is still under construction. The key reasons for not using storyboards and communities of practice are the lack of reward systems for knowledge sharing, leaving experts and participants without motivation to attend formal or informal meetings.

4.10 Hypothesis Testing

Hypothesis testing is a statistical method used to determine whether sample data provides sufficient evidence to infer that a condition holds true for the population. Hypothesis testing requires proposing a null hypothesis (H0) and an alternative hypothesis (Ha), which are mutually independent.

For chi-square goodness-of-fit tests, the hypotheses are formulated as:
H0: Significant correlation exists between two variables
Ha: No significant correlation exists between two variables

Typically, this involves comparing the p-value with the significance level, rejecting the null hypothesis when the p-value is less than the significance level.

As shown in Table 8 , gender and experience have significant effects on selected variables. However, the significance levels between highest education level and knowledge acquisition (0.000<0.05), knowledge sharing (0.002<0.05), and knowledge creation (0.000<0.05) are all less than 0.05, showing no significant impact.

Descriptive statistics for the six dimensions are further presented in Table 9 .

The results show that the variable knowledge application has a mean of 3.7542 with a standard deviation of 0.42999. Additionally, other variables have means around 3.0, with knowledge storage showing the highest standard deviation at 1.12446. This indicates that respondents provided positive answers to related questions.

4.11 Matrix Diagram

Figure 9 [Figure 9: see original paper] illustrates the matrix diagram used to simultaneously assess relationships among several groups of variables. For example, a strong association exists between knowledge acquisition and knowledge application.

4.12 Problems in Knowledge Management

The survey asked respondents to evaluate various knowledge management activities implemented in the software industry, as shown in Table 10 .

4.13 Organizational Participation

Knowledge management can build knowledge capabilities that influence and improve organizational performance. The authors learned from respondents about their companies' investment interests in knowledge management.

Based on the results described in Figure 10 [Figure 10: see original paper], management across all three companies understand that knowledge management is critical to software development activities and that support for it is essential (ORGP1). However, Company A lacks appropriate knowledge strategies that map knowledge to value creation (mean value of 2.69) (ORGP2), placing it at a nearly unfavorable level that requires serious consideration. Although Company A's management cannot identify expertise resources within the organization (ORGP5), they effectively utilize external resources including customer knowledge (ORGP6). Additionally, management in all three companies assume responsibility for facilitating learning, including continuous transformation between individual and organizational learning (ORGP3) and learning from past experiences (ORGP4).

4.14 Interview Explanations

Table 11 presents interview summaries with management, while Table 12 presents summaries with senior software engineers.

5 Discussion and Conclusion

This study investigates knowledge management practices in Sri Lankan software companies. To maintain competitive advantage, software companies must recognize the importance of applying knowledge management within their organizations. The findings reveal that although companies have not yet established comprehensive ICT infrastructure, software developers are willing to access various knowledge sources including public websites, internal networks, project documents, and source code. Meanwhile, software knowledge stored in knowledge repositories significantly benefits software developers and enhances their creativity, yet not all software engineers utilize existing knowledge. Additionally, establishing adequate search and retrieval facilities and enriching knowledge repository content are issues requiring serious future consideration.

In summary, although software developers recognize the importance of knowledge management, existing tools, techniques, and methods cannot effectively address knowledge management challenges in the software development industry. Participants' responses highlight the importance of organizational knowledge structure and organizational learning. Moreover, beyond formal and informal meetings, few mechanisms or methods exist for sharing experts' tacit knowledge. The findings demonstrate that organizational culture affects knowledge sharing, a issue software companies must address seriously in the future. Additionally, this study provides evidence for future research on knowledge management practices in the software industry and promotes future investigations.

The authors plan to conduct additional quantitative and qualitative data collection to understand more organizational and other contexts, enabling better comprehension of knowledge management and identifying support mechanisms for organizational learning in the software industry.

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Shanmuganathan Vasanthapriyan: Responsible for research conception and design, data collection, and paper writing;
Tian Jing: Responsible for research framework design, paper revision, and final approval;
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Note: Figure translations are in progress. See original paper for figures.