Managing Knowledge in Global Software Development Projects

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Abstract: Software is increasingly developed in global projects, and such projects are challenged by distance, time zones and cultural differences. Knowledge management is central in order to ensure effective development of a product with the right features with the right level of quality. A central question is then what knowledge management approach to apply in global software development. This article draws on established research in software engineering, combined with three focus groups in two global companies to discuss what knowledge management schools are appropriate on a global level and what approaches are relevant for greenfield global projects.

Keywords

Knowledge management, global software development, software engineering, information systems, focus group.

Introduction

Software is increasingly developed by global teams [1, 2]. In small and medium-size to large companies, projects are set up with several development sites separated by distance, time zones and cultural differences. In the past, companies focused on outsourcing to low-cost countries. Today, companies often choose to establish own sites that enable access to sufficient personnel and knowledge while ensuring the necessary control over turnover and protection of intellectual capital [3]. Recent advancements in version control systems, and the availability of both low-cost and high-end communication technology have made global collaboration easier. However, many companies are still striving to increase the effectiveness in global software development projects.

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As Ågerfalk and Fitzgerald [4] describe, global software development projects are challenging due to a lack of informal contact that can reduce awareness of work tasks, and complicate face-to-face meetings. Further, cultural differences may create misunderstandings, and inconsistent work practices can impinge effective coordination.

Knowledge management [5] is central in order to ensure effective development of a product with the right features with the right level of quality. A common definition of knowledge management is Davenport and Prusak´s: ‘‘a method that simplifies the process of sharing, distributing, creating, capturing and understanding of a company’s knowledge” [6]. Studies of teamwork show how shared knowledge impacts team effectiveness. Shared knowledge of both what is to be developed as well as the development process is crucial in order to avoid costly misconceptions and misunderstandings. The ability of team members to take over other members’ tasks at times of high workloads is important in order to ensure progress in the project by using resources on high-priority tasks. Further, a study of software development performance shows how better integration of domain and technical knowledge leads to increased software development effectiveness and efficiency [7].

In this article, we examine strategies for knowledge management, and through a focus group study of three global collaborations we describe current practice and discuss our research question: *How should knowledge be managed in global software development projects?*

Knowledge Management in Global Software Development

Knowledge management in global software development projects has received some attention, for example, Desouza et al. [8] argue for new methods and models as companies increase global development. Oshri et al. describe practical methods for managing knowledge in global projects [9]. The number of documented empirical studies devoted to knowledge management in global software engineering is small [10], while a review of knowledge management in software engineering in general found 29 empirical studies [11]. Thus, one may be curious whether we can apply some of the lessons learned from general knowledge management in the particular setting of global software development. As Ågerfalk and Fitzgerald point out, there are three particular challenges in global software development – temporal, geographic and socio-cultural distances [4]. In the following, we briefly present findings from the general studies of knowledge management in software engineering and discuss how these findings may apply to global software development. We use Earl´s framework of knowledge management schools [12]. This is a widely used framework that divides knowledge management into five approaches called ‘schools’ (as described below). It has been applied in software engineering e.g. by Bjørnson and Dingsøyr in their systematic review on knowledge management [11].

The systems school focuses on applying technology for knowledge management by storing knowledge in repositories. Studies in software engineering found that repositories have been used to share different types of knowledge, such as risk assessments and software design experience. One study shows broad application of an easy to use repository [13]. Because knowledge is codified, this approach works well

with geographic and temporal distance. There might be socio-cultural challenges, for example, different preferences for which knowledge to maintain, how knowledge is communicated, and to what level of detail knowledge should be described.

The cartographic school focuses on knowledge maps and creating knowledge directories. A study of a skills management system found that this tool was in use for a variety of purposes, from allocating resources, searching for competence, identifying project opportunities, to upgrading skills [14]. The tool was found to enable learning both at individual and company level. Knowledge maps and directories on company intranets could be beneficial when the company is distributed geographically. However, this is most effective when the temporal distance is small and knowledge can be transferred orally. This school might be also vulnerable to socio-cultural distance. For example, what kind of knowledge is mapped in a skills management system, and how skill levels are evaluated could vary.

The engineering school focuses on processes and knowledge flows in organizations. A number of studies in software engineering describe this approach, focusing primarily on processes for mapping knowledge, conducting project retrospectives, mentoring programmes, and describing work processes such as in the Capability Maturity Model [15]. This approach relies on explicit knowledge and therefore it is not affected by geographic or temporal distance. However, knowledge about processes might be interpreted differently in diverse socio-cultural settings.

The organizational school focuses on networks for sharing or pooling knowledge. Many companies have applied this approach through establishing internal communities of practice, groups who interact regularly for sharing knowledge on a common topic of interest. The systematic review [11] refers to one study, which claims that communities built on existing networks are more likely to be successful. In a community, both tacit and explicit knowledge may be exchanged but typically the explicit knowledge exchange is less formal than in a knowledge repository. Lessons learned reports and templates are typical examples. Knowledge is usually communicated orally in physical or virtual meetings. Thus, this school can suffer from challenges related both to geographic, temporal and socio-cultural distance.

The spatial school focuses on how design of the office space can facilitate knowledge management. This can range from better facilitation of knowledge sharing where people meet, by setting up whiteboards close to water coolers or coffee machines, to making use of open-plan offices. The most used approach in agile development is to establish taskboards, which provide visible information regarding the project status to both team members and other stakeholders', and facilitate during formal and informal meetings. The systematic review [11] did not identify any studies on this knowledge management approach in software engineering. Notably, this approach depends on physical co-location, and from studies of agile software development it seems to work well for small teams.

In summary, application of knowledge management approaches in global settings is expected to differ. Temporal and geographic distances primarily affect the ability to access and share knowledge, while

socio-cultural distance introduces challenges with aligning the ways knowledge is shared and maintained (see Table 1). This puts limitations on the selection of knowledge management approaches. We expect that traditional global projects would rely on systems and engineering schools, as codified information sharing is less vulnerable in the face of the distances. Agile development on the contrary implies the dominance of spatial and organizational schools with its focus on sharing of tacit knowledge. The cartographic school can provide a cost-effective means for managing knowledge globally for both traditional and agile projects.

Table 1. Knowledge management schools and their application in global projects.

School	Focus	Aim	Potential challenges in global development*
Systems	Technology	Knowledge bases	SC
Cartographic	Maps	Knowledge directories	SC
Engineering	Processes	Knowledge flows	SC
Organizational	Networks	Knowledge pooling	G, T, SC
Spatial	Space	Knowledge exchange	G, T

* T indicates challenges introduced by temporal, G – geographic and SC – socio-cultural distances.

Method

In order to explore how knowledge is shared in global projects we organized three focus group workshops in two organizations. Both organizations are large international companies developing complex embedded software solutions utilizing product-oriented processes. “Alpha” is headquartered in Sweden and is rapidly extending its operation in Asia. We held two workshops focusing on collaborations involving sites in Sweden, China, and India. “Beta” is headquartered in US. Our study focused on collaborations involving sites in Sweden and Russia. Organizations were selected on the basis of accessibility and their interest in taking part in this research. As for knowledge management, we believe they represent typical global companies, without any particular recent explicit knowledge management initiative. Alpha is a mature agile development environment, while Beta has recently started agile development. The time difference between the sites is seven hours in workshop 1, 3.5 hours in workshop 2, while participants from workshop 3 have fully overlapping work hours after an adjustment on the Russian site. Representatives from both companies nominated participants and projects for the workshop based on their interest in improving particular collaborations. Participants with different roles (developers, designers, testers, and team leads) were selected to cover different experiences. Detailed information about the participants is given in Table 2.

Table 2. Workshops overview

	Participants	Collaboration	Format	Focus
W1	6 participants from Sweden	Sweden - China	Held in Sweden, moderated by two researchers.	A large-scale software development project. Each site is involved in developing a component for a compound system and contributes to the shared parts of the platform. The project follows Scrum [16].
W2	4 participants from Sweden 3 participants from India	Sweden - India	Held through a video-conference, moderated by two researchers at Swedish site.	Two related software development projects. Each site is involved in developing a product that has interfaces to a common platform. Both projects follow Scrum.
W3	7 participants from Russia	Sweden - Russia	Held in Russia, moderated by one researcher.	Three small-scale software development projects. In all projects development is primarily done in Russia, while project and product management is in Sweden. Two out of three projects recently implemented some elements of Scrum, and will continue to expand the use of agile methods in the future.

We used the focus group research method [17] in order to capture employee´s perceptions, opinions, beliefs and attitudes to knowledge management. This method is applicable to quickly obtain information on emerging phenomena through structured, moderated discussions with groups of practitioners. In a workshop lasting four hours, we explored knowledge management strategies, challenges and potential improvements through the following key questions:

- What knowledge is important for efficient completion of daily work?
- Which knowledge resides locally, and which is shared globally?
- How is knowledge shared and maintained?
- What knowledge is easy to share, and what introduces challenges?

The moderator instructed the participants who engaged in the workshop activities for individual brainstorms and group discussions. In the co-located workshops we used whiteboards and flip charts to structure results. Participants used post-it notes and markers to document answers to questions posed by the moderator. In the video-conference workshop, involving two sites, one of the moderators documented the results using a mind-map software tool. The results were shown on a shared screen to all participants. Minutes were sent to all participants for validation. Thereafter, the description of knowledge management practices in the minutes were coded into knowledge management schools, for example "use of knowledge repositories" was coded as the systems school. The results were presented to the companies for verification and feedback. Figure 1 is based on this material.

Global Knowledge Management in Practice

Investigating knowledge management practices in three focus groups, we found that knowledge management approaches varied. Many knowledge management schools were in use locally and globally, as shown in Figure 1. We also see that the companies found the majority of the important knowledge hard to manage both globally and locally in Beta, while most knowledge was found to be easy to manage in Alpha. One possible explanation is related to the nature of work conducted in each case. In Alpha we explored two collaborations, in which product components shared a platform. The majority of work was conducted solely in one location, and only the shared platform part required joint coordination. In Beta we explored an offshore site, which was represented by participants from different projects. Most of these projects involved maintenance of systems previously developed in Sweden. This could impact the complexity of the necessary knowledge management.

We present findings from each workshop in relation to each school in the following (see Figure 1).

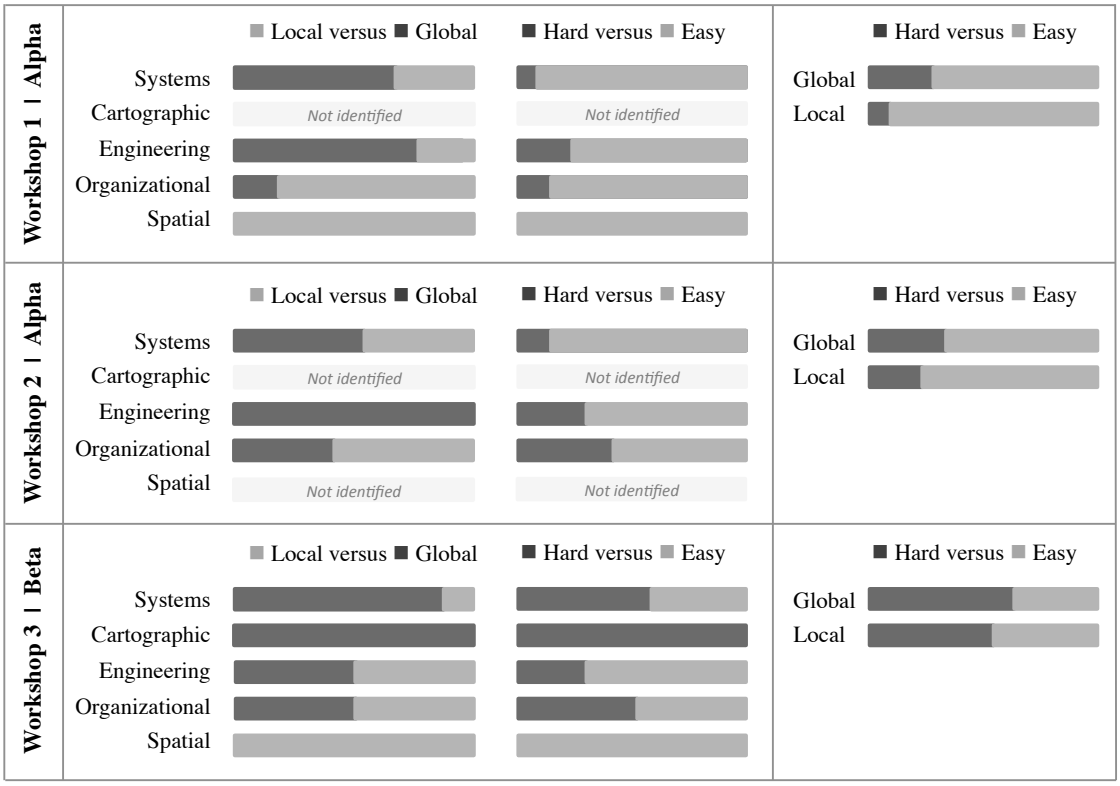

Figure 1. Focus group results coded into knowledge management schools, and characterized after participants' opinion on whether the knowledge was managed locally or globally, and whether it was hard or easy to manage.

Systems school: In all three workshops, participants described extensive use of knowledge repositories available in corporate databases, intranets and local project file servers. From Figure 1 we see that this approach is mainly used for managing knowledge globally, and the two most mature agile projects see this knowledge as easy to manage, while the project in Beta finds much of this knowledge hard to manage. A common challenge with this school is that repositories easily become information

graveyards, where knowledge is stored but not retrieved. Also, codifying knowledge is usually more expensive than transferring it orally. Participants from all three projects complained about the search functions in the repositories. In workshop one in Alpha, we identified a lack of awareness of how to search effectively, and in Beta we learned that some knowledge repositories contain limited knowledge, but are easy to search, while others contain much, but are difficult to search. The challenge in this approach is thus primarily related to how the knowledge repository is developed, which supports the theoretical argument that this school is robust to temporal and geographic distance. The socio-cultural distance did not seem to influence the use of the systems school. This may be because all sites have a long history of collaboration, and this might pose problems in greenfield projects.

We learned that progress and future plans are not reported across the sites. Participants in workshop one at Alpha described that each site managed the knowledge locally in their own repository. Therefore, this knowledge was inaccessible for remote colleagues.

Cartographic school: Interestingly, we found only one example of the knowledge management approach that was classified as cartographic. It was a wiki page containing indexed links to project information sources in one of the projects in Beta, and this was maintained globally. An overview of "what is where" in global projects is important, since each site may sometimes use local knowledge repositories or many repositories for different types of knowledge.

Gaps in understanding "who knows what" were stressed in all three workshops. Although co-located team members knew each other well, familiarity with colleagues from other teams (in large projects) and from remote sites was challenging. Formal meetings usually provide individuals with knowledge about where they can obtain further knowledge [18]. However, if such meetings are held only locally, the cross-site links are not created. The knowledge of who has decision power was missing in both projects in Alpha.

Although cartographic knowledge management solutions seem easy in theory, they require commitment and joint effort from all collaborating parties, and therefore are hard to put into practice. We learned that there is a great need for introducing easy to use cartographic knowledge management strategies in global projects. These are likely to increase awareness and improve coordination.

Engineering school: Distance introduces challenges for coordination, and one approach to relieve this is to define and standardize work processes across sites. This is addressed by the engineering school, which has been implemented as a global effort in Alpha, while Beta has a mixture of locally and globally supported processes. This knowledge is mainly seen as easy to manage, but from the Alpha projects we learned that the ways of working differ across sites, and even within a site, when a large project is divided into teams. This corresponds to previous findings on challenges with standardizing work practices through role and process descriptions on intranets [19].

Some processes were missing, thus prohibiting knowledge sharing across project teams. In Alpha, feedback from team retrospectives is stored in a corporate repository, but not shared across teams. Only a few participants in Sweden were aware of a process improvement initiative, which targeted cross-team

learning, presenting their findings once a year. Learning from each other becomes even more challenging across remote sites.
Some processes are also hard to describe. In Alpha, we learned that sharing knowledge about the notion of good and bad code quality and test quality was challenging due to socio-cultural differences.

Organizational school: This approach to knowledge management develops communities, where members keep in touch through video-conferences, physical meetings and by using telephone and email. These communities can be within and across sites. Most of the knowledge managed through these approaches was local in Alpha, and evenly local and global in Beta. The Alpha participants in workshop two found this knowledge the most hard to manage, while it was moderately hard in Beta. Much of the product and project knowledge remains tacit and is accumulated in the heads of experts. Distance introduces new challenges for sharing this knowledge. While knowledge locally is shared through personal contact networks and during formal and informal meetings, reliance on an organizational knowledge management school in global projects becomes more challenging. Participants from the Alpha project explained that certain knowledge such as code anatomy, product architecture, implementation and dependencies, was not shared globally. This could explain why the knowledge managed with these approaches was not seen as hard in this project. Live meetings necessary for sharing such information are challenged by time zone differences. In Beta, we learned that developing a cross-site community requires “bridgeheads”, a person staying at the other site to get acquainted with the remote organization and learn from experts or a person from the other site who can facilitate this. Participants from Beta admitted that it is very difficult to create a community with remote colleagues. Building personal relationships without face-to-face interaction takes a long time.

Spatial school: This school relies on the use of office space to foster knowledge management. The most obvious approach in agile development is the use of taskboards to visually communicate the work status of a team. This was in use in the Alpha projects and in one of the projects in Beta. The knowledge managed through this approach was seen as easy to share, especially since it was maintained locally. We have not found sufficient evidence that this school could work effectively over distance. In Alpha, the teams that use agile methods locally share knowledge on taskboards and innovation boards to capture ideas that are unavailable across sites. One project in Beta recently started using a video camera to show a taskboard to the other site, however it is unlikely that a temporary video-feed of the board will create the same form of awareness of tasks as in the room where it is physically present. In fact, in the mentioned case the local team in Beta was also forced to maintain the board in a separate meeting room instead of having it close to the team’s working location. Although advanced tools for video-walls ensuring real-time projections from remote offices are available on the market, we have not found them applied in the companies studied.

Conclusion

In this article, we asked the following research question: "How should knowledge be managed in distributed global software projects?" Our focus group investigation shows that a number of approaches

are actively used in organizations that have developed software globally for years. Both Alpha as a mature agile development environment and Beta as a company beginning to use agile methods make use of a variety of schools. This study shows that knowledge management is challenging both at local and global levels, and companies need to focus on both.

Rather than selecting one school, companies should carefully consider several. We have found that some approaches are perceived as both easy and hard depending on the context. Developers working in global projects need sufficient information to create a shared knowledge of the task, shared knowledge of the team, task awareness and presence awareness — important coordination enablers [20]. This has to be in place, despite of the challenges induced by temporal, geographic and socio-cultural distances. In the following we describe concrete advice drawn from relevant theory of knowledge management [11] and findings identified in our focus group study:

Identify the main global challenges in the project: are there barriers for knowledge management due to geographic, temporal or socio-cultural distance?

Define what should be shared locally and globally: Proactively assess what needs to be shared globally and what can be shared locally. Discuss different strategies for managing knowledge in the project as early as possible. We found that knowledge sharing needs varied between different sites. Participants regarded our focus group workshops as useful in facilitating awareness of challenges, and we suggest others to apply this practice.

For local knowledge management: Make use of approaches that require little resources first, like the spatial, organizational and cartographic schools. Make use of visual boards, build on existing networks and establish easy to use overviews of employee knowledge. Finding the right balance of local and global knowledge management can be difficult, as the focus groups show.

For global knowledge management: Select an approach after evaluating the challenges inherent in your global software development project. Remember that cross-site collaboration needs to be fostered over time. This can be done through collaborative workshops and practicing on team tasks, but also supported through indexes and profile pages to support remote teams in learning who knows what and what is where, as this represents an economic way to share knowledge globally.

Avoid known knowledge management pitfalls: Companies often rely on codified knowledge and process standardization efforts in global projects. We recommend that companies learn from successful cases in the systems school when making use of knowledge repositories. Avoid repositories that create impediments to knowledge sharing, are only used in certain sites or not used at all. We also stress the need to make as much use as possible of approaches that promote sharing of tacit knowledge, unless there is a large potential in reuse of explicit knowledge. Finally, apply strategies to improve work

practice as identified in studies in the engineering school. General findings and our focus group study indicate that describing work methods on an intranet will not lead to changes in work processes.

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