The Importance of Knowledge Management Practices in Overcoming the Global Software Engineering Challenges in Requirements Understanding

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ABSTRACT

Going offshore has become a norm in current software organizations due to several benefits like availability of competent people, cost, proximity to market and customers, time and so on. Despite the fact that Global Software Engineering (GSE) offers many benefits to software organizations but it has also created several challenges/issues for practitioners and researchers like culture, communication, co-ordination and collaboration, team building and so on.

As Requirements Engineering (RE) is more human intensive activity and is one of the most challenging   and important phase in software development. Therefore, RE becomes even more challenging when comes to GSE context because of culture, communication, co-ordination, collaboration and so on. Due to the fore mentioned GSE factors, requirements' understanding has become a challenge for software organizations involved in GSE. Furthermore, Knowledge Management (KM) is considered to be the most important asset of an organization because it not only enables organizations to efficiently share and create knowledge but also helps in resolving culture, communication and co-ordination issues especially in GSE.

The aim of this study is to present how KM practices helps globally dispersed software organizations in requirements understanding. For this purpose a thorough literature study is performed along with interviews in two industries with the intent to identify useful KM practices and challenges of requirements understanding in GSE. Then based on the analysis of identified challenges of requirements understanding in GSE both from literature review and industrial interviews, useful KM practices are shown and discussed to reduce requirements understanding issues faced in GSE.

Keywords: Global Software Engineering, Global Software Development, Requirements Engineering/Understanding, Knowledge Management, Knowledge Management Practices.

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CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

1 INTRODUCTION

1.1. Introduction and Background

With the advent of modern technologies the world has been changed to global village, therefore software industries have also started focusing from shifting traditional form of co-located development to offshore development. Besides, globalization of markets, technologies, economical factors, availability of resources and methodologies has certainly influenced software development by in large [1].

Global Software Engineering (GSE) has been adopted widespread and gaining fame with the passage of time. Besides, as in GSE development teams are dispersed geographically therefore its major advantage is closeness to market/customer. Further, GSE main driving force is economical factor i.e. as the product is developed in less time and resources used [1, 2]. Moreover, GSE offers many benefits like cost effectiveness, shorter development time, skilled people and less use of resources [3].

Despite the fact that GSE has offered many advantages, it has also created several problems and challenges for researchers and practitioners. As GSE teams are dispersed geographically so therefore several problems occurs like communication, culture issues, trust, co-ordination, Knowledge Management (KM), Requirements Engineering (RE) and so on [2].

Knowledge Management is considered to be the most important asset of an organization. Before going deeper, first knowledge can be defined as "Knowledge is experience or information that can be communicated or shared" or can be defined as "Knowledge, while made up of data and information, can be thought of as much greater understanding of a situation, relationships, causal phenomena, and the theories and rules (both explicit and implicit) that underlie a given domain or problem" [6]. Further, KM is a very broad field; it not only enables organizations to create and share knowledge but also helps in increasing co-ordination, understanding and resolving communication and culture issues [7].

With an increasing awareness and importance of the 'knowledge' residing in organizations, there has been a rise in awareness of methods and tools to retain and grow this knowledge. The most obvious and arguably most successful discipline to achieve this has been KM [8]. Besides, software development is rapidly evolving day by day with many people involved in it. Further, as there is lack of resources, but demands from market are increasing, due to which software organizations are facing problems in productivity growth. Software organizations has large amount of knowledge resided in their processes, methodologies, people, culture and working environment. So therefore, there is a need to share and transfer this knowledge in/across organizations in order to understand, manage, to identify customer and business needs, know-how of culture and co-ordinate throughout the software development life cycle effectively [9].

Knowledge is basically of two types namely tacit and explicit. Tacit knowledge is the form of knowledge which is resided in people mind and which cannot be easily transferred, shared and understood. Whereas explicit knowledge can be codified, shared, understood easily and is context independent [7].

In GSE, all organizations are involved in knowledge intensive activities which may be tacit or explicit. Knowledge which is shared or transferred must be managed and understood by organization members in order to get most benefits out of it. KM helps companies enrich and share this knowledge residing in products, processes and people by various tools and methods. This KM exercise is often helped by Information Technology (IT). Besides, KM

becomes especially of interest due to the fact of culture diversity, communication gap and coordination problems across organizations [4].

Likewise, RE phase is considered to be crucial and tricky phase in software development life cycle and especially becomes more challenging in GSE. As in GSE, organizations are spread geographically so therefore communication and coordination becomes more difficult which also has impact on the requirements being gathered. Further, requirements' understanding is considered to be one of the biggest and challenging issues for academia and industries in GSE from last decade [5, 10]. In addition, requirements understanding problem can arise at any stage of RE like when requirements negotiation, communication, prioritization and specification takes place. For example in requirements negotiation the development teams might want to know what is the rationale behind including the new requirement or changing the requirement? Therefore development team working offshore might misunderstood due to some tacit knowledge which needs to be made explicit. The reason being this knowledge is tacit is due to lack of communication, lack of co-ordination between offshore teams, different time zones and culture differences [11, 5].

1.2.   Problem Description
Most of the businesses which have adopted product line have crossed land structures and requires protection, storage and effective management of the know-how obtained from clients, insuring continuity and efficiency of the entire production lifecycle. This means that they have to deal with multi cultural requirements from their offshore productive units from customers. A software engineer who has to deal with such requirements is actually dealing with a multi cultural tacit knowledge transferred in the shape of requirements. This needs to be explicit before it gets processed. This scenario requires a complete synchronization among different offshore units. Moreover, culture always has some influence on the generated requirements, which the experiences of offshore regional teams reflect as well. It is truly an indication of complex and error prone condition. To reduce this complexity and the expected error to minimal proper KM practices are required. The KM tools/methods can better assist good software engineering practice [5, 10].

1.3.   Aims and Objectives
The aim of the thesis is to propose KM practices which can overcome/reduce the problem of requirements understanding in GSE.

 In order to meet the aim/goal, following objectives are set.
- Analyze current KM practices in GSE.
- Identifying challenges of requirements understanding in GSE from literature.
- Analyzing challenges of requirements understanding in industries involved in GSE.
- Identifying the key aspects in proposing KM practices and tools for requirements understanding in GSE.
- The KM practices and tools will provide possible solution to the challenges faced in requirements understanding in GSE.

1.4.   Research Questions
In the context of this thesis following research questions will be addressed.

RQ1. *What is the current state of practice of KM?*
A literature review will be performed in order to know the current state of practice of KM. Besides, the focus will be solely on those KM practices which can be useful in overcoming requirements understanding issues in GSE. Moreover, the intent is to gain background knowledge for the study and to provide an overview to the readers. Besides, it will also serve as an input for answering RQ3.

RQ2. *What are the challenges of requirements understanding in GSE?*
Basically this research question will be addressed in two stages. First of all the challenges of requirements understanding in GSE will be identified through a thorough literature review. In second stage an industrial survey will be conducted in order to identify the challenges of requirements understanding faced by industries involved in offshore development/GSE. Moreover, it will also serve as an input for answering RQ3.

RQ3. *How KM practices helps to reduce requirements understanding problems in GSE?*
The intent behind addressing this research question is to propose and discuss KM practices for reducing requirements understanding problems faced in GSE identified in RQ2. Moreover, the knowledge and answers gained from RQ1 and RQ2 will be used in proposing KM practices.

1.5.　　　Expected Outcomes
This thesis will present the knowledge gained through answering the above mentioned research questions. In particular, the thesis will describe the KM practices which are concerned with requirements understanding in GSE. Besides, the authors will identify the challenges of requirements understanding in GSE. Moreover, KM practices will be proposed which can be used for bridging/reducing requirements understanding problems in GSE.

1.6.　　　Motivation for the Research
RE is considered to be the crucial phase of Software Development Life Cycle (SDLC) because it's really hard to know what the system shall do, which things are to be included/excluded, putting certain constraints, understanding customer needs and wishes [12]. Further, RE is not only difficult in in-house development but becomes even more challenging in GSE. As in GSE teams are dispersed geographically therefore it becomes more difficult to exactly know the demands and wishes of the customers due to huge differences in culture, values and beliefs. Besides, as RE requires more and more analysis and negotiation in order to make correct decisions and implement those requirements correctly. Further, due to different time zones, language and trust, problems of communication and coordination occurs. As GSE is evolving day by day so therefore there is a need to cope with requirements understanding problem. Further, researchers and practitioners are facing this dilemma from last decades and are in search of possible solutions. Software organizations are now realizing the usefulness and effectiveness of embedding KM practices in their organizations. Besides, KM especially becomes more crucial when GSE perspective is discussed because KM is really helpful to solve communication, overcoming culture, language and trust barriers. Likewise, the knowledge resided in culture; people mind in the form of experience and working environment is of utmost importance for organization success and should be managed and shared efficiently. In the context of this thesis work, the tacit knowledge present with requirements needs to be made explicit which is due to culture, co-ordination and communication problem. Moreover, this thesis is aimed to provide KM practices which can help practitioners and researchers to solve requirements understanding problems faced in GSE to minimal.

1.7.　　　Research Methodology
There are three types of research methodologies namely qualitative, quantitative and mixed methodology. However in the context of this thesis the authors have used qualitative approach [77, 79]. First, a thorough literature study was performed in order to collect material related to KM and challenges of requirements understanding in GSE. This is essential to gain a fundamental understanding of those research areas, the underlying concepts and to know the current state of research. The literature study embraces the study of

existing articles, books and web references, if appropriate. However, it was taken in to account that a literature study can be time consuming and to reach consensus [77].

Second, after identifying the KM practices and challenges of requirements understanding in literature the authors conducted survey in software industries which were involved in GSE to identify and map the practices with our findings. The data was collected primarily through interviews with appropriate number of participants [77, 78]. The motives behind using interview are [80]:

- They are useful to know the interviewees experience with the problem.
- To know the opinions of interviewees about the problem.
- To identify and investigate industrial practices for the intended problem.

As the research approach of authors study is only qualitative, therefore, the authors have used interviewing technique for conducting survey in software industries involved in GSE. Besides, there are three types of interviews namely; structured interviews, unstructured interviews and semi-structured interviews. Structured interviews are those interviews in which the interviewer asks questions in '*Yes-No*' form i.e. always leads the discussion to a specific direction. In unstructured interviews, interviewee is considered to be the source of both questions and answers because a lot of discussion is made broadly on the intended issue/topic which yields useful relevant information. In semi-structured interviews, both structured and unstructured interviews approaches are adopted. Moreover, for this study the authors have used semi-structured interviews. The aim to adopt semi-structured interviews was due to the fact that it enables the interviewers to ask any type of questions whether specific or open-ended questions [80].

After identifying and mapping the challenges of requirements understanding in GSE i.e. both findings of literature and industrial survey results, KM practices were proposed for reducing requirements understanding problems in GSE.

2. CHALLENGES OF REQUIREMENTS ENGINEERING IN GLOBAL SOFTWARE ENGINEERING

2.1. Requirements Engineering

Software development has been problematic since 1960s, which in turn leads to late, lower quality, unsatisfied customers and over budget delivery of the system. According to [13], one of the main reasons behind these problems is difficulties and misunderstanding of requirements.

Requirement Engineering (RE) plays a vital role in the development of software products. A requirement represents the behavior of a system, information regarding application domain of a system, constraints on operation of a system, or specifications of a system's property. Therefore, the success and failure of a system depends upon the degree of compliance of a system with its requirements specified [13].

RE involves in finding or revealing, documenting or specifying and maintaining or managing a set of requirements for a software product. Further, RE is a complicated, volatile and diverse field of software engineering therefore, each and every organization has their own way of performing RE activities. In addition, there is no silver bullet/formal process for requirements activities due to different abstraction levels in requirements written by different organizations. Besides, the differentiation in levels of abstraction may be due to the technical maturity of an organization, disciplines involvement like engineering and managerial levels, organizational culture and application domain. However, software researchers and practitioners agreed upon the core activities of RE i.e. requirements elicitation, requirements analysis and negotiation, requirements documentation and requirements validation. Besides, as requirements are volatile in nature i.e. evolve over time, therefore, a process of requirements management is always connected in parallel with all other RE activities, for consistency and control [13].

2.2. Importance and Challenges of RE in Software Development Life Cycle (SDLC)

As RE is the first activity/phase of SDLC, therefore, it has great importance throughout all phases of software development i.e. design, development, testing, and maintenance. According to [14], the process of RE should be defined in more detailed and organized way in order to get better quality software products. Further, after completion of RE phase the output of this phase serves as input to the design phase, and then design phase serve as an input to the development and so on. If the initial input from the requirements to the design and so on is understandable, unambiguous and correct, then the resulting product will be of high quality and consistent with customer needs. On the other hand, if the initial input is ambiguous and has conflicts, then the output of SDLC will be over budgeted, late and low quality product. According to [14], correcting of errors generated in the RE phase later in project e.g. maintenance, can cost up to 200 times than correcting the same errors during the RE phase. Hence, RE is the core and most important phase of SDLC.

According to [13, 14], despite the importance of RE process (phase), it has also brought problems (challenges) with itself which have destabilized the needs and expectations of organizations and stakeholders. Furthermore, different challenges have been identified in the literature faced during requirements engineering phase like inadequate requirements traceability, complexity of application and so on, for further details see [13, 14, 15]. Besides, some common challenges found in literature are given below. The intent behind the selection of these challenges for this study is the applicability and existence of these challenges in RE activities both in traditional form of development (onsite development) as well as in an

organization which is involved in GSE. Further, RE is human intensive activity and also the focus of this study is more towards human based activities like to make requirements more understandable with the help of KM practices like meetings, visiting, and culture know-how. Therefore, authors have selected challenges which are more related to human based activities and have not selected those challenges which are specific towards technical side. In general there are no strict boundaries for selection but the intent is to give an overview of the challenges e.g. inadequate requirements traceability also have impact or is a challenge of RE, but due to the scope of this study authors have not discussed here.

2.2.1. Misunderstanding of Requirements
According to [14, 13, 10], lack of requirements understanding may be due to the improper communication, organizational policies and political factors, culture diversity, knowledge management and so on. Moreover, misunderstanding of requirements may arise due to conflicts, ambiguities, incorrect interpretations and incompleteness of requirements because different stakeholders have different views and perception about a specific problem.

2.2.2. Inconsistent and Incomplete Requirements
Requirements inconsistency and incompleteness always results in low quality products. Furthermore, requirements consistency means that there should be no contradiction between requirements whereas completeness means that needed services or constraints should not be missed out. Moreover, requirements should always be consistent and complete before its implementation for getting high quality products which in turn will lead to satisfied customers [13, 14].

2.2.3. Customer Needs
Most of the time customer needs are neglected due to cost, schedule, resources, lack of domain knowledge and product knowledge. Moreover, requirements are not implemented according to customer needs and thereby do not reflects the real needs of the stakeholders [14].

2.2.4. Stakeholders Communication
Stakeholder's proper communication is also considered as one of the most crucial challenge in RE because different stakeholders fail to communicate requirements effectively with other stakeholders for resolving and negotiating requirements problems like inconsistency or incompleteness and so on. Besides, due to inadequate communication among different stakeholders, the resulting requirements document/specification is not understandable. Therefore, requirements should be properly communicated and negotiated before implementation phase in order to resolve all conflicts and ambiguities [13, 42, 43].

2.2.5. Organizational Culture
Each and every organization has their own policies, rules, standards and ways of working which also have great impact on requirements in the form of confidentiality and security. Further, political issues within organizations also has effect by in large on RE activities. All this represent the culture of an organization [13, 14, 43]. Moreover, this issue may also arise between different units of an organization which are dispersed geographically.

2.2.6. Lack of Requirements Management
Requirements management is the process during which changes to the requirements are managed. Furthermore, requirements change occurs due to customer needs, new policies of an organization or government, new technologies [13]. So therefore, managing such changes is a challenge for organizations and has been considered as problematic in literature [13, 14]. According to [16], a requirement must satisfy the condition or capacity of a system, therefore, requirements identification, registration, organization and verification is necessary.

Hence, due to the lack of proper requirements management up to 70% of requirements are hard to identify and 54% are unclear and unorganized.

2.2.7. Lack of Defined Responsibility

Proper responsibility assignment is also a challenging issue in RE. One of the main reasons is the involvement of different people and properly understanding their role and responsibilities. For example, some tasks may not be performed by a team member due to the reason that he/she will think that some one else is responsible for performing it. Therefore, some requirements may be left ambiguous and contradictory [13, 14].

2.2.8. Involvement of Stakeholders

As RE is a challenging task due to the involvement of multiple stakeholders from different backgrounds i.e. software engineers, system analysts, testers, end-users and so on. Furthermore, these stakeholders may be numerous and distributed (may be geographically). Therefore, their needs, expectations and perceptions may vary depending on the environment in which they are performing their tasks. Their goals may not be explicit and it is a challenging task to articulate each and every stockholder's goals, which in turn has effect on the overall RE process.

2.3. Global Software Engineering

The steady and irreversible norm of globalization of businesses has been started from last decade, and particularly in field of software outsourcing business [2]. As world evolves with the passage of time due to introduction of new technologies and computer applications, therefore the pace of globalization has dramatically increased and have made the world more interdependent than ever. Furthermore, due to globalization not only products and finances but also ideas and cultures circulate more freely. Particularly, software outsourcing companies also tend towards globalization due to satisfied customers, high quality and due to rapid and cheaper development of software products to compete in the targeted market.

Due to the advancement in communication media, especially with the emergence of internet systems, has increased the trend of team working across different sites. Further, it has considerably helped organizations which are dispersed geographically despite of communication problems, coordination problems, language differences, culture differences and time-zone differences [17, 18]. Global Software Development (GSD) is therefore the commonly increasing practice/phenomenon in software companies which is also called as Global Software Engineering (GSE) i.e. GSD and GSE are used interchangeably.

2.3.1. Factors which Fuels Organizations Towards GSE

Different researchers have identified several factors which fuels organizations specifically software organizations towards globalization like Mockus et al [18], Prikladnicki et al [19], Vanzin et al [20], and Carmel [21], have mentioned the following factors which compels software organizations to adopt GSE:

- Availability and usage of resources successfully and cost-effectively.
- Organizations can take advantages of proximity to the market.
- To exploit market opportunities, with the formation of quick global software teams.
- "Around-the-clock" development of software products is possible by taking advantages of different time zones.
- GSE provides flexibility to gain the opportunities wherever offered around the globe.
- GSE also provides opportunities in the reduction of development cost.
- GSE also gives the label of globalize presence i.e. "we are a global player".

By adopting GSE, all these factors offer great advantages to software organizations. A major advantage of developing a product close to targeted market or customers is the reduction of overall time to the market and hence it will helps an organization to save budget for a specific project. Further, by developing products globally different people from different environment/culture, different level of experience and technical background come close together and work on a specific project which can take an organization towards innovation and creativity [22]. Besides, by developing projects an organization have easy access to the pool of human resources; therefore, there is a great chance of having a new set of individuals that fulfill their needs and expectations. Furthermore, geographically distributed teams may work 24-hours through effective use of time-zone differences and follow-the-sun strategy [17]; this therefore helps in reducing development cost which in turn will reduce the overall development budget of a project. Organization can also gain benefits from GSE [2], in essence that they can split (modularize) their tasks of a project according to the experienced and available skilled human pool in a specific region which in turn will help to reduce the dependencies among different teams therefore the cost of traveling and coordination can be reduced.

Moreover, as several software organizations have reported successful completion of their projects instead of having several challenges and problems but, still GSE is increasing gradually and becoming a norm due to promising benefits being offered to organizations [23, 24].

2.3.2. GSE is Challenging/Difficult

It is true that GSE is becoming more and more prevalent among organizations especially among software organizations. According to [18], "in year 2000, 185 of Fortune 500 companies outsourced software development to India alone and the amount of outsourcing grew at a 53% yearly rate according to report by the National Association of Software and Service Companies (NASSCOM) ". Apart from the benefits GSE provides it has brought up number of challenges like culture differences, geographical dispersion, loss of communication richness, coordination breakdown and loss of teamness [21]. Moreover, the following discussion is also summarized in the form of a table based on several authors focus on different challenges as shown in Table 01.

Table 01: Contribution of Several Authors Identified GSE Challenges

	Culture Differences	Geographic Dispersion	Loss of Communication Richness	Co-ordination Breakdown	Loss of Teamness	Time Zone Difference
Mockus et al [18]	⚫		⚫			
Fenema [25]	🔴	🔴				🔴
Herbsleb et al [2]	🔴		🔴	⚫		
Smith et al [26]	🔴				🔴	
Prikladnicki et al [19]	🔴					
Vanzin et al [20]	🔴	⚫	🔴	🔴	⚫	🔴
Mockus [38]			⚫	⚫		
Krishna et al [39]	🔴					
Nicholson et al [28]	🔴	⚫				⚫
Herbsleb et al [31]			⚫	⚫		
Herbsleb et al [40]			🔴	⚫		
Herbsleb [41]				🔴		
Komi-Sirvio et al [27]	🔴		🔴			
Battin et al [24]	🔴	🔴	🔴	🔴	🔴	
Ebert et al [22]	⚫					
Herbsleb et al [23]	⚫	⚫	⚫	⚫		⚫
Carmel et al [29]			🔴	🔴		⚫
Carmel [21]	🔴	🔴	🔴	🔴	🔴	⚫
Daurte et al [30]		🔴	🔴	⚫	🔴	⚫
Conchuir et al [44]	⚫	⚫				🔴

🔴 → Focused and discussed thoroughly challenges

⚫ → Less discussed or has only mentioned challenges

### 2.3.2.1.	Culture Differences

In GSE different teams from different countries are involved in the development of a specific product. Therefore, they have different cultures in different dimensions e.g. style of communication, response time, attitudes, commitment, ways of thinking and ways of solving problems and so on, which requires close cooperation among different individuals from different culture backgrounds [2]. According to Carmel [21], culture have several dimensions like national, organizational, ethics and bodies of manners, ideologies, strategies, tactics and manners for survival in society, technical, professional and team culture. In short,

culture diversity encompasses norms of behavior, values and language [25]. Likewise, four types of culture have been mentioned in [26]:

- Individual: This represents personal outlook, style or personality of an individual.
- Functional: This represents the outlook of a specific department way of working.
- Organizational: This represents the characteristics differences between companies, such as an IBM as opposed to Dell [21].
- National: This represents the differences which are related to nationality [21].

Many researchers have found culture difference as a challenging issue [2, 20, 21, 24, 26], which should be considered and cannot be neglected in GSE. Because it can cause serious and chronic misunderstanding which in turn will lead to unexpected results of a project. According to [27], 52% of the respondents have mentioned culture difference as a problematic issue. Another study [20], has mentioned that culture differences have 33% negative impact on project activities. These different studies, in different ways, stress the point for researchers as well as practitioners that as in GSE numerous members from different nationalities and backgrounds are involved therefore, there is a need to take the issues of culture seriously whether it is national or organizational. Furthermore, according to [28], culture issues can "make or break an offshore project".

As different dimensions of culture discussed earlier, this can create misunderstandings and even dissatisfaction within a project. Likewise, same actions can be interpreted differently within any culture either national or organizational [27]. Further, culture differences can create problems of misinterpretations or misunderstanding, if different dimensions of culture are not spread throughout organization and among different units of organizations. A good example of misinterpretation is given in [27]; problem of reporting was considered a regular action on one site while at another site it was considered as an insult. Likewise, ways of doing work can be different between sites, like one site can not give much importance to some of project activities, such as finishing a deliverable according to the planned date, communication regarding a decision or change. In addition, different countries and organizations may have different terms and concepts. Additionally, sense of time and commitment may also vary between different countries and continents, which are considered to be the key players in project's success and failure [20].

Despite the negative impacts or problems generated by culture diversity in GSE, it has some positive impacts as well. Culture can equally be important for organizations involved in GSE like organizations can develop their functional and organizational culture according to their own customs and values. Hence, such type of organizational culture can help in common understanding regarding solving different problems especially in case of RE [10]. Further, if people from different cultures understand customs and values of one another then they will operate more cooperatively than collocated [26].

To reduce or overcome culture differences, some sound and thorough actions needed to be taken to improve coordination and communication among different team members dispersed across different countries or continents. For example by visiting to a specific site, when the problem is too ambitious or ambiguous i.e. needs communication face-to-face because it is an effective way of lowering ambiguities and misinterpretations caused by culture differences. Besides, training can also be a good way of knowing about an organizational and national culture. Moreover, to alleviate culture differences these factors should be kept in mind and considered seriously; such as thorough communication among overall units, defining and using predefined terms and improving language skills, and producing and sharing knowledge regarding cultures issues and customs [27].

2.3.2.2. Geographic Dispersion

Geographic dispersion means to divide some functional part or department of an organization and take it to a metropolitan area or across the globe. In simple words, geographical dispersion is the allocation of different units of an organization through some physical distance. And hence a product will be developed by the coordination and thorough communication of different members of such dispersed organization. According to [26], people involved in such dispersed organizations are called virtual teams. Further, as teams are required to do tasks and perform well but virtual (dispersed) teams fail to perform, because of trust, less-coordination and communication. Besides, Carmel [21] quoted statement of a global project manager, "It's hard, it's hard. No one in their right mind would split up their development effort just for the fun of it. It's much easier when someone is close to you. Technology has done a lot to ameliorate- but not to turn dispersed development into an advantage".

Collocation is comparatively simple than geographical dispersion because of physical proximity like having near access to others by walking distance in same building or in the adjacent building. Therefore, it is very easy for managers to keep eyes on tasks either by observation or MBWA (Management By Walking Around). Besides, Carmel [21] has mentioned numerous advantages of collocation, such as shorter distance among product development team members, shorter the communication lines and hence the feedback about a specific problem or issue can easily be solved. Further, in collocation as teams are so tight to each other therefore trust increases and miscommunication decreases among team members. In short geographical dispersion is like "out of sight out of mind" [21]. But on the other hand Carmel [21], also mentioned some disadvantages of collocation like informal and oral communication may proceed to sloppy documentations and procedures like half-finished task.

Survival without globalization in present era seems very hard. Carmel [21], Vanzin et al [20] and Carmel et al [29], have mentioned many factors due to which collocation is less feasible in the present era comparatively to geographically dispersed organizations, like cost advantage, large labor pool, close to important customers and close to market (see Section 2.3.1).

On other hand geographical dispersion has also brought some challenges which complicated the situation of product development like coordination, control, culture differences, language barriers and communication problems [29, 30]. According to [29], organizational units dispersed geographically hard to function well without coordination and control. Hence, to alleviate complication faced by organizational units dispersed geographically, possible suited solution could be six-centripetal forces proposed by Carmel (see Section 2.4.1.2). Moreover, effective use of communication and collaboration technologies can also help to reduce the challenges faced by organizations due to geographical dispersion [30].

2.3.2.3. Loss of Communication Richness

As distance between organizational units separated from each other increases, communicating effectively becomes more challenging and problematic. Further, developing software across boundaries has made the situation more complex because of difference in culture, language, and availability of good technology infrastructure which affects the communication among different units of an organization [27, 30]. Besides, Vanzin et al [20] have shown a direct relation of geographical distance between units of an organization and the technology used for communication. This means that the success of geographical dispersed units is directly dependent on the communication media used and coordination between them which helps in communication a lot. Likewise, effective communication can play vital role in the success of a global software project [29]. Further, communication becomes more important when the project picture is not clear and needs more discussion [2]. In addition four categories of communication and interaction have been mentioned in [30]:

1. Same time, same place like face-to-face meetings.
2. Same time, different place like video or audio conference.
3. Different time, same place like chat room or shared a file on network.
4. Different time, different place like email or voice mail.

As software development is a human intensive activity which requires communication so that development team can interact with one another within same and outside building. Further, the communication type may be formal or informal and synchronous or asynchronous depending on organizational setup (dispersed geographically or collocated). According to [27], 88% of single site software projects have face-to-face meetings when team members communicate with one another, which reduced up to 4% during dispersed sites. This means that face-to-face communication is one of the best ways of communication but geographical dispersion lacks it. In collocated environment, frequent interactions among team members are always very effective. Likewise, most of the problems are solved through group work and interacting with one another, but when distance comes in frequency of communication among team members reduces considerably [31].

As GSE organizations do not have sufficient funds to visit other units for meetings, therefore, different communication media can be used for solving conflicts, ambiguities and misinterpretations between sites. Most commonly used technologies are video conferencing, audio conferencing, chatting, telephone calls, net meeting, and emails and so on. Furthermore, proper infrastructure, management and utilization of these telecommunication media can help in trust building and commitment among team members. Moreover, it can also help in reduction of misunderstanding caused due to culture difference, time zones difference and language barriers [20].

2.3.2.4.   Coordination Breakdown

In GSE perspective coordination is the activity through which different tasks of each organizational unit are integrated so that the units contribute for setting goals and objectives [29]. Therefore, close coordination and collaboration is very necessary for reaching on consensus about a specific issue or problem throughout the development cycle of a product. In addition, coordination is the working relation with other team members because about 70% of the time developers spend on working with others [21].

In GSE way of coordinating is different from collocated like visiting some one table personally or corridor talks to communication media, organizational culture and processes used. Furthermore, different dimensions have been identified for coordination in globally distributed units such as shared processes, shared and detailed project management, shared past experiences and background knowledge [23]. Therefore, distributed units of an organization put further burden on the mechanism of coordination like teams cannot coordinate by visiting someone office to resolve a problem. Likewise, due to difference in time zones, even a quick phone call regarding a specific problem cannot resolve issues. Further, in distributed environment more coordination among teams is needed therefore, load on communication media and other communication channels such as multi-site project management package increases [21].

In GSE coordination is the key phenomenon and thorough understanding is required for types of coordination because it is the need for success in GSE. Further, Carmel et al [29], supports coordination in a way that without proper coordination, it is hard for organizational units to function well and geographical distance has introduced many difficulties in it. Therefore, managing and organizing coordination mechanism through introducing formal and informal ways of interaction within different units to alleviate coordination breakdown.

2.3.2.5.   Loss of Teamness

Software development consists of different teams like requirements engineers, architects, developers and testers. Therefore, teamness is a fundamental issue which should be taken care of because it provides benefits to organizations whether offsite or onsite environment. According to [21], "a good team does not ever need to communicate much" because members of good team know about themselves, their strengths and weaknesses, they know about the specified goal and the processes used for the achievement of their goals.

Unfortunately distance has created many hurdles for team members dispersed globally like diversity in teams, loss of cohesion, trust building, culture differences, and language differences. Besides, different people having different culture, knowledge backgrounds, difference in time zones and language etc complicates the situation even more for teamness in geographically dispersed units. Furthermore, using different development processes [24], organizational standards, organizational cultures and policies also affect dispersed teams because all such complications make communication and collaboration among teams more difficult and hence teamness is lost. Therefore, it is a challenging task for managers involved in global projects to create and maintain teams which are working in such a volatile and complicated environment [20, 26, 30].

According to [26, 30], teams involved in GSE are also called virtual teams and such teams have strong justification for business. Furthermore, organizations can get many benefits from such teams like they speedup development time, helpful in creating useful ideas and innovations if they are properly managed, organized, formalized and encouraged. Additionally, effective use of communication and collaboration media can also play a vital role in the success of virtual teams. In addition [21] "trust needs touch" and is the foundation for all teams whether dispersed or collocated. Therefore proper trainings and employees' introduction with each other at the beginning of a project are also suggested for building trust which will in turn create teamness among virtual teams [26].

2.3.2.6.   Time Zone Difference

Time zone is a challenging issue and which has negative impacts on GSE activities [44]. Furthermore, organizations working in large time zones face more problems than organizations working in fewer time zones like arranging meeting time between units because the selected time may be suitable for one unit and problematic for other unit. Likewise [23], time zones create enough problems when some urgent meetings or interaction is necessary. Besides, time zones are particularly problematic when there are some conflicts or ambiguities among units on some tasks especially during RE activities. Additionally, some inconsistencies may arise when different units using different processes, policies and so on, therefore, in this case intense interaction is needed which is a bit harder in having larger differences in time zones.

Apart from the negative impacts that time zone has on GSE activities; organizations can also benefit from it by adopting follow-the-sun strategy. Organizations can organize and integrate their tasks very tightly between different units and hence unfinished tasks are transferred between units. Furthermore, by adopting this fashion a virtual 24-hours development environment is created which in turn will increase the development time [17].

Carmel et al used word *temporal distance* for time zone differences [29], which can be reduced by using synchronous and asynchronous communication. Further, asynchronous communication is best for those organizational units which have high temporal distance as compared to synchronous communication [20, 25]. For example, it is easy to check an email (asynchronous) in office hours any time rather than having chat (synchronous) with someone late at night. In addition, asynchronous communication is less effective because one cannot observe facial expressions, body language, context, speed and tone of voice. On the other hand synchronous communication has high level of richness in communication because

direct frequent communication, direct dialog helps in understanding, body language and tone of voice etc. Moreover, synchronous communication is more effective way to resolve conflicts and ambiguities between different units of an organization.

2.4. GSE Puts New Challenges on RE

As discussed earlier RE is the crucial phase in SDLC and is the first phase of software development which represents the needs and expectations of stakeholders. Therefore, to fulfill needs and expectations of different stakeholders' thorough specification, communication and negotiation, documentation and management, and so on of requirements is necessary for both organization and customers. However, these activities are difficult due to the challenges (see Section 2.3.2).

RE itself is very difficult but GSE has also brought new challenges like culture difference, geographical dispersion, time zone differences and so on which has made even more complicated the RE process [10, 32, 33, 34]. Likewise, RE activities are becoming more challenging in GSE due to lack of interaction among teams across boundaries [32]. Furthermore, one of the most common problem with RE is the involvement of different stakeholders in it, like requirements analysts, system analysts, developers, and designer. On the other hand, in distributed environment of GSE these groups of people of RE are further enlarged due to the involvement of cross-functional groups of stakeholders. Therefore, resolution of misunderstanding and conflicts of requirements become more difficult because it then requires effective communication, coordination among stakeholders to manage, negotiate and specify a specific requirement issue.

The GSE challenges which are identified and discussed (see Section 2.3.2) are not solely GSE challenges but they are also applicable to RE within dispersed units. Likewise, it is obvious from literature that these challenges has impact on RE like, affected requirements management [16, 35], requirement specification [36] and requirements communication and coordination [32, 10].

Different problems have been reported in requirements engineering activities due to GSE challenges. According to [33, 34], culture have different values and beliefs which lead requirements towards misinterpretation and miscommunication among teams. For example, developers having different cultures may interpret requirements differently according to their own values and beliefs. In addition, these culture values and beliefs present with requirements in the form of tacit knowledge are very hard to understand and may create problems in requirements understanding like misinterpretations, conflicts and ambiguities. Likewise, time zone may also impact requirements especially requirements communication because the time available for synchronous communication is short in large time zones which may lead to delay and misunderstanding of requirements. Furthermore, inadequate-communication and coordination may also lead to conflicts, misunderstanding and misinterpretation of requirements, due to which different RE activities like negotiation, prioritization and analysis can be affected by in large [10, 34].

In GSE a lot of work has been done on RE where different challenges and solutions to these challenges have been identified and mentioned. But all of the research is specific to only one RE activity like requirements management and requirements specification etc. In addition, they all have tried to resolve problems technically by developing tools and techniques. However, our focus is on requirements understanding because it is one of the most challenging issue considered in GSE for both researchers and practitioners [5, 10]. As the problem of requirements understanding can arise during any activity of RE like requirements negotiation, communication, prioritization and management. For example requirements analyst during requirements prioritization may prioritize requirements according his/her own culture values and beliefs which might not be understandable to the designers or developers on the other site of organization due to the tacit knowledge present with requirements. The

reason being is the tacit knowledge present with requirements due to lack of sharing culture knowledge, lack of communication, lack of coordination and so on [11, 5]. Moreover, GSE challenges (see Section 2.3.2) have greatly affected requirements understanding globally as shown in Figure 01.
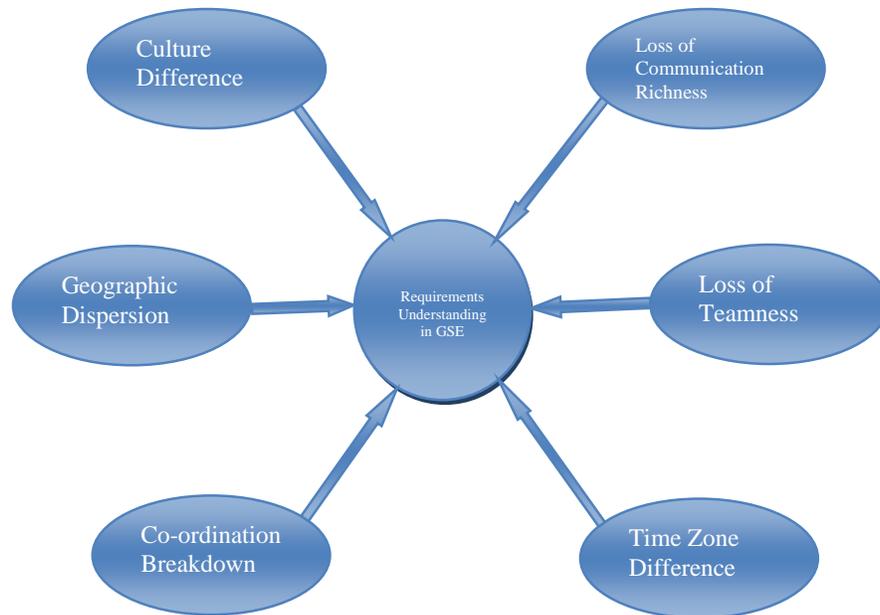
Figure 01: GSE Impacts on Requirements Understanding

2.4.1. Carmel Centrifugal and Centripetal Forces

As GSE is difficult due to the challenges (see Section 2.3.2), Carmel [21] calls those challenges as Centrifugal Forces except time zone. But we believe that time-zone is also one of the challenging issues which should be handled carefully, because if organizational units have larger time zone differences then it has effect on all activities of software development especially RE which requires more communication and coordination. Therefore, in the context of this thesis the authors are only considering Carmel work on GSE because the five centrifugal forces along with time zone and Six Centripetal Forces mentioned by him cover all aspects of GSE.

2.4.1.1. Centrifugal Forces

According to Carmel [21], centrifugal force is a physical force which takes away an object from its center. In addition, these centrifugal forces are basically the challenges faced in GSE environment. Further, software organizations involved in GSE faces these centrifugal forces in one way or other way around. Likewise, due to these centrifugal forces different teams of an organization like requirements analyst and developers and so on become far away from one another to communicate and collaborate intensely. Moreover, five centrifugal forces identified by Carmel [21] are given below and are already discussed (see Section 2.3.2).

1. Cultural differences
2. Geographic dispersion
3. Loss of communication richness
4. coordination breakdown
5. Loss of teamness

Time zone is among the challenging issues of GSE [24, 20,17] and also some authors claims it specifically affects and is important for RE activities [34, 10], therefore the authors take it

as sixth centrifugal force. Moreover, as RE requires continuous and intense collaboration, coordination and communication in time but due to larger differences occurs in time zones causes' breakdown in communication. Hence, the sixth centrifugal force which affects RE and it especially create problems in requirements understanding, is also shown in Figure 02.
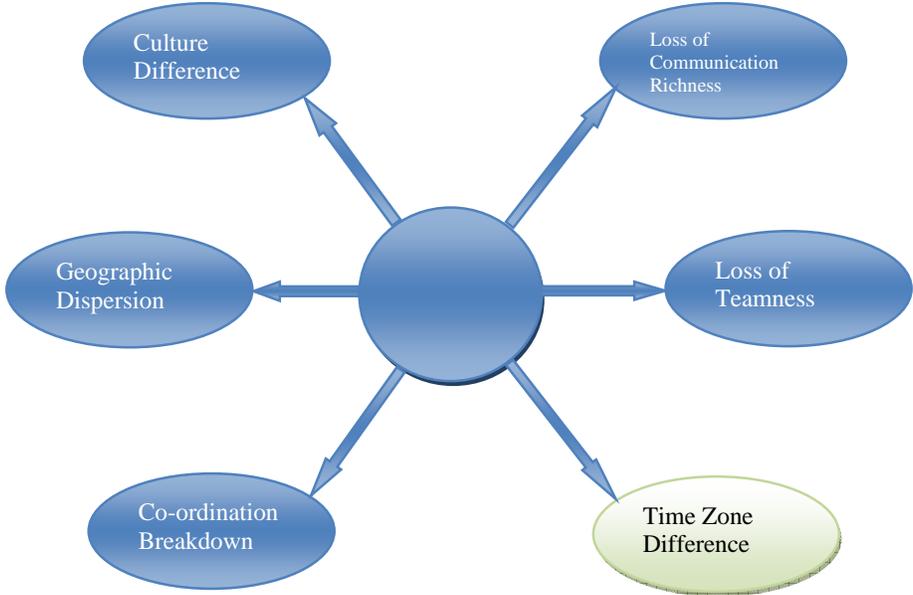
Figure 02: Centrifugal Forces (Modified) [21]

2.4.1.2. Centripetal Forces

According to Carmel [21], centripetal force is the force which takes objects towards center. Besides, these forces are the solutions to centrifugal forces so therefore these forces help in resolving issues and problems created by six centrifugal forces i.e. GSE challenges. In addition, the solutions proposed by Carmel are useful for different teams dispersed geographically i.e. can collaborate and communicate globally. The Six centripetal forces are also shown in Figure 03 are given below:

1. Collaborative technology
2. Telecomm infrastructure
3. Managerial techniques
4. Development methodology
5. Team building
6. Product architecture
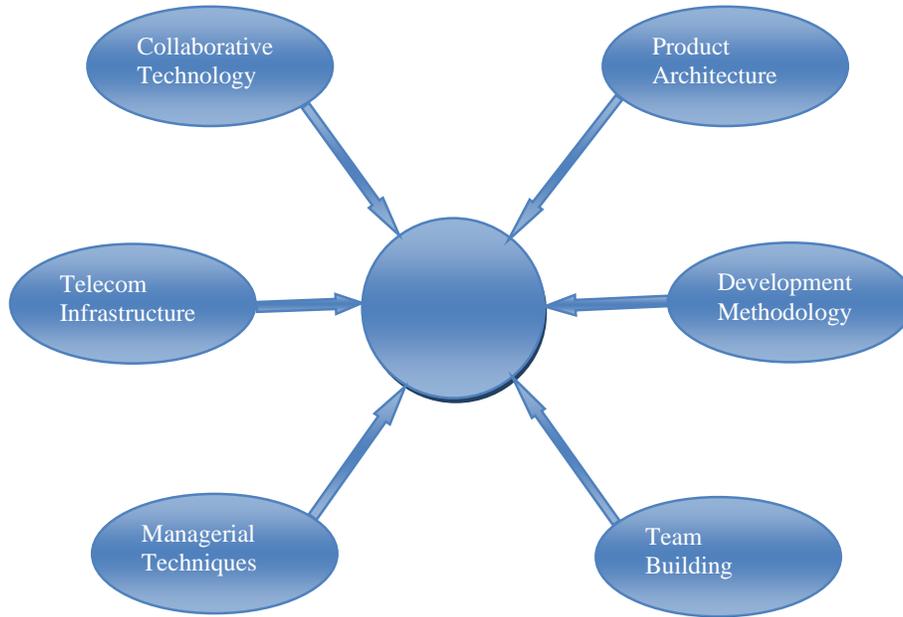
Figure 03: Centripetal Forces [21]

Different solutions have been proposed by researchers for working in GSE environment like multimedia meeting system, video channel, and electronic workspace and so on to solve problems in requirements negotiation [37]. Further, problems of culture, communication and time zones in requirements specification can be reduced by close coordination and awareness of cultures and so on [36]. In addition, requirements management problems can be alleviated by communication and discussion, managing changes and managing project knowledge [35]. But the solutions provided by Carmel i.e. centripetal forces, for the resolution of problems and issues generated by centrifugal forces (see Section 2.4.1.1) gives clear picture of GSE challenges. Moreover, in the context of this thesis the authors will focus on Carmel [21] work i.e. to supplement Carmel solutions with the help of KM practices/tools.

2.5.   Summary of the Chapter

The aim of this chapter was to answer the research question i.e. "What are the challenges of requirements understanding in GSE?" The answer of this question has been addressed in this chapter only from literature review. This chapter contributed to research question in several stages. In first stage some common challenges of RE are discussed to give readers an overview and background knowledge. In second stage GSE challenges have been identified and discussed thoroughly with the intent to know pros and cons of identified challenges and to get a deep insight of each challenge identified. In third stage the impact of identified challenges of GSE on RE has been addressed with the intent to find the challenges for requirements understanding and fulfill the main content of research question. In fourth stage Carmel centrifugal and centripetal forces have been discussed in detail because the main task of author's study is to supplement Carmel solutions with the help of KM, which will be discussed in next chapter.

3 KNOWLEDGE MANAGEMENT

3.1. Introduction

Software development is a very complex, knowledge intensive and rapidly changing activity with different people involved in it [76]. Likewise, as time evolves technology changes, development methodology changes, processes changes and people interest changes so therefore there is a need to retain this knowledge properly in organization for reuse in future. In addition, as software development has several phases thus many people are involved in it and therefore it becomes harder to know each other when size of organization is large. Further, software organizations are always aiming towards increasing productivity and quality of software, less cost and time to market which is only possible to reduce rework by learning from past, never repeating mistakes and make use of proper resources i.e. money, people and time [9]. Most of the software development organizations are now shifting towards global software development due to several benefits it offers like locally available skilled people, satisfied customers, less use of development time and cost and better productivity and quality [2, 68] (see Section 2.3.1). However, despite the benefits it provides, it has also brought some challenges like trust, culture differences, loss of communication and so on [10, 5] (see Section 2.3.2). Furthermore, researchers have identified and mentioned different solutions to deal with GSE challenges such as Carmel centripetal forces (see Section 2.4.1.2). However, according to authors view despite the solutions provided by Carmel, it is important to implement Knowledge Management (KM) strategies. Moreover, the aim of this chapter is just to give an introduction and overview to the field of KM.

3.2. Knowledge Management (KM)

Knowledge Management has been considered the most important asset of an organization. Furthermore, organizations are now realizing its importance due to its success factors like reuse of past knowledge, experiences and innovations. KM can be defined as the process of sharing, distributing, organizing, creating, storing and understanding of knowledge about organization policies, processes and products [45]. Further, as the size of organization grows it becomes very hard to know each other, share experiences and ideas. Likewise, to find appropriate solutions of the problems and store knowledge for future use, therefore, a proper strategy is needed to store and retain this most important intellectual asset i.e. knowledge of organization. Besides, organizations are also facing difficulties when an expert leaves an organization because the expert knowledge is lost. Therefore they have to hire new people which require more trainings and time, thus there is need to retain and manage effectively expert knowledge to be used in future [9].

3.2.1. Data, Information and Knowledge

In order to know what knowledge is it is necessary to first make a differentiation between data, information and knowledge. Data is considered to be the combination of words, sounds and figures without some contextual details. Further, data could be the result from some survey in form of raw numbers, or some assumptions in form of words. Whereas information is considered to be the structured i.e. arranged in some mannered set of data with some useful contextual details and semantics [71]. Like, after some analysis or calculations on data it becomes information which can provide the reader some results regarding particular things e.g. survey. Knowledge can be defined as "knowledge can be understood to emerge from application, analysis and productive use of data and/or information". In addition, knowledge is used as means to understand both data and information [7].

Data, information and knowledge are interrelated with each other. Further, data and information are useless without any useful knowledge. In order to grasp something out of data and information some relevant and appropriate level of knowledge is required.

Likewise, they are not only interrelated, but both data and information also serves as building blocks for creating new knowledge [46]. Knowledge is not used just for interpreting data and information respectively, but also used for the appropriate use and application of data and information respectively. Thus knowledge is used for the analysis of data and information and thereby to grasp some results out of it.

In author's opinion the relationship between data, information and knowledge can be given as shown in Figure 04. From Figure 04 it is clear that for changing data into information some useful intellectual values i.e. contextual details are added and so is the case for knowledge [7]. Further, there is no exact single definition of knowledge, data and information respectively as can be seen in Table 02. Different authors have given different opinions and perception while defining the terms data, information and knowledge respectively.
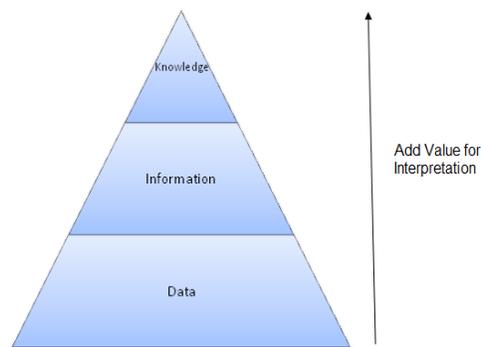
Figure 04: Data, Information and Knowledge [70]

By closely observing Table 02 in which several authors have defined data which in author's opinion has one thing in common that data is combination of words, raw images and sounds without any contextual details.

In author's opinion the different definitions of information given by several authors reveal one thing in common i.e. information is arranged set of data which provides reader with some contextual details. For example, Davenport [49] defines information as "Data with relevance and purpose", Wiig [53] defines information as "Facts organized to describe a situation or a condition" and Spek and Spijkervet [52] defines information as "Data with meaning". Further, by analyzing the different authors definitions have one thing in common; information is the structured set of data with some contextual details except Davenport and Prusak [8], defines information as the "A message meant to change the receiver's perception" which focuses on messages and dependent on the sender of the message. Moreover, information is considered to be the structured set of data with some details which helps the readers in understanding the situation or a particular condition.

By comparing Hislop [7] definition of knowledge to the mentioned authors in Table 02 it is clear that knowledge is about the application of experiences and insights of individuals in a particular situation. Further, knowledge is dependent on individuals i.e. people have different perceptions and approaches for looking and solving a problem. Therefore, different people may have different methodologies for analysis of a problem and situations. Moreover, by applying relevant knowledge to data or information in a particular situation helps in productive use of data or information i.e. adding meaning to both and helps in know-how of situation.

Knowledge can thus be defined as "Knowledge is a fluid mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluation and incorporating new experiences and information. It originates and is applied in the minds of knower's. In organizations it is often embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" [8].

The definition provided by Davenport and Prusak [8], seems a bit different from Hislop [7] like knowledge is related as a mean for understanding and analyzing data/information whereas in other it is related to experience. But, the common things in both of them are expert insights, appropriate selection, use and application of experiences. Likewise, values for understanding, interpretation and use of data and information are needed respectively. Moreover, knowledge is the ability of individuals own mind and thus they are applied differently i.e. methods at different situations.

Table 02: Definitions of Data, Information and Knowledge [46]

Author(s)	Data	Information	Knowledge
Wiig[53]	---	Facts organized to described a situation or a condition	Truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how
Nonaka and Takeuchi[50]	---	A flow of meaningful messages	Commitments and beliefs created from these messages
Spek and Spijkervet [52]	Not yet interpreted symbols	Data with meaning	The ability to assign meaning
Davenport[49]	Simple observations	Data with relevance and purpose	Valuable information from the human mind
Davenport and Prusak [8]	A set of discrete facts	A message meant to change the receiver's perceptions	Experiences, values and insights and contextual information
Quigley and Debons [51]	Text that does not answer questions to a particular problem	Text that answers the questions who, when, what and where	Text that answers the questions why and how
Choo et al [48]	Facts and messages	Data vested with meanings	Justified, True believes

By summarizing all of the above discussion the author suggests the following suitable definition shown in Table 03 for data, information and knowledge respectively. In addition, the motives behind these definitions are: as discussed earlier the definitions of data and information respectively are needed in order to know what is and is not knowledge. Further, in Table 02 different authors have defined data and information respectively but Table 03 covers almost all aspects to clearly differentiate them. Likewise, in the context of our thesis knowledge is more related to experience and depends on individual own capability to shape and reshape new knowledge. Moreover, knowledge can be created during sharing experiences i.e. individuals own capabilities and then applying it in relevant situation for solving problems.

Table 03: Data, Information and Knowledge Definitions

Data	Data are combination of raw images, numbers, words, sounds which is gathered/collected as result of some measurement or observation without any contextual details [7]
Information	Structured Data i.e. arranged in some meaningful manner or pattern with some contextual details [7]
Knowledge	"Knowledge can be understood to emerge from application, analysis and productive use of data and/or information" [7] "Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluation and incorporating new experiences and information. It originates and is applied in the minds of knower's. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" [8].

3.3.   Types of Knowledge

In KM literature there has been several types of knowledge given but the most common types found are "Tacit vs. Explicit" and "Individual vs. Group/Social" knowledge which are discussed in detail below:

3.3.1. Tacit Knowledge vs. Explicit Knowledge

Tacit knowledge has been defined by several authors but Polanyi [47] was the first who introduced and defined the term tacit knowledge. According to Polanyi [47], tacit knowledge is very hard to communicate or share and is personal i.e. deeply rooted in actions. Further, tacit knowledge is very hard to articulate in words and requires some metaphors and drawings [54]. Besides [7], as tacit knowledge resides in human minds so therefore it is subjective and personal in nature. According to Polanyi [47], we have more knowledge and know-how than ours ability to convey, shows that often people know more but they cannot express in words which represents the tacit nature of knowledge they have. For example, it is very hard to describe in words how to ride a cycle, how to drive aero plane and how to play cricket. Because all this sort of know how cannot be described in words but requires practical demonstration, training and teaching to learn it.

Tacit knowledge is embedded in human minds i.e. somewhat intuitive and personal so therefore it is not an easy task to store it electronically. Additionally, tacit knowledge is deeply rooted in individual actions, crafts and is therefore shared and created continuously [55]. Moreover, as tacit knowledge is personal so therefore it requires training, drawings, practical demonstration, interaction, dialogue for sharing and learning [54].

Explicit knowledge can easily be shared, communicated, stored and understood. From its name it is clear that explicit knowledge is impersonal [7, 54]. Besides, explicit knowledge is thus documented and every one can take benefit out of it i.e. publically available with the help of some Information Communication Technology (ICT) tools [55]. Moreover, explicit knowledge refers to codified knowledge available in form of documents, books, figures, maps, diagrams and manuals [7].

In the context of this study requirements are always misunderstood due to tacit knowledge present with each requirement. This tacit knowledge may be due to culture, lack of proper communication and coordination, lack of motivation, lack of background knowledge and so on e.g. Two different units A and B working offshore might misunderstood requirements due to tacit knowledge of culture present with each requirement. Thus tacit knowledge always needs to be made explicit through frequent discussions, dialog and trainings to make requirements more clear and understandable.

Knowledge either tacit or explicit depends on the capability level of receiver i.e. up to how much extent did the person grasp and learn out of it. However, the author's not only argues that the knowledge being grasped depends on receiver capability but it also depends on the level of details the knowledge being specified in documents or tips given during coaching of football. Moreover, knowledge being tacit or explicit has same importance and requires efforts for managing it.

3.3.2. Individual Knowledge vs. Group/Social Knowledge

Individual knowledge is the knowledge possessed by individual in their minds. This knowledge can be in the form of experiences, abilities and skills of individuals. This concept of individual knowledge by Nonaka has been opposed by several authors and they have claimed that not only there is individual knowledge but there is also knowledge present in our working environment [7].

Group knowledge is the kind of knowledge which is present or possesses in working groups. Further, group knowledge can be either tacit or explicit depending on nature. For example, collective explicit knowledge is documented system of rules and formalized organization routines and collective tacit knowledge includes informal organization routines, stories and methods of doing work [7].

In this study individual knowledge and group knowledge both have same importance because individual experience about past projects, knowledge of people and culture helps a lot in requirements understanding whereas group knowledge also helps in requirements understanding like organization standards for requirements specification, policies and task division.

3.4.　　　　Knowledge Management Strategy

Knowledge management strategy is very important for both kinds of knowledge either tacit or explicit. Furthermore, knowledge storing is not considered as a challenge but finding the relevant knowledge is a dilemma for organizations. Likewise, organizations have experienced personnel but identifying, knowing and reaching a relevant person for a specific problem is a challenge. Additionally, as knowledge has become useful asset of organizations and therefore sharing and transferring knowledge to correct persons at right time is the challenge needs to be solved. The challenges include knowledge fragmentation, overload and de-contextualization. For example, "Knowledge, which is trapped inside the minds of key employees, in filing drawers and databases, is of little value if it is not supplied to the right people at the right time" and ''They cannot see the forest because of the trees'' etc. Therefore, there is a need for some strategy to ensure, pursue and preserve both tacit and explicit knowledge and it even becomes more necessary for all those organizations which are dispersed geographically [56]. Moreover, the essence is to make use of organization knowledge easily by efficient way to identify relevant experts, knowledge stored in documents and sharing the knowledge. The commonly used approaches for preserving explicit and tacit knowledge are codification and personalization strategies respectively [56, 57].

For this study the knowhow and appropriate use of KM strategy is important because in GSE as teams are dispersed geographically so therefore knowledge of people, culture, organization, past experience, who knows what and so on should be available to everyone easily within no time. Besides, in GSE it is hard to know each other and access to relevant documents i.e. past stories. Furthermore, KM strategy is one of the driving factors in requirements understanding in GSE because if there is some issue to be resolved then relevant expert identification is necessary.

3.4.1. Codification Strategy

The knowledge which is stored in repositories or databases is called codification strategy. Likewise, knowledge which is articulated/can be articulated in words is codified/codification. In this approach knowledge is codified or stored in documents [57, 72]. Further, the documents may be manuals, organization policies and rules. Codification strategy provides many benefits to organization like storing the documents enables the employees to access the relevant knowledge documents from anywhere. Likewise, it is especially important for those organizations which are scattered geographically [56], reuse of knowledge, learning (past success and failure stories) and innovation (making new shape to previous ideas and tasks) helps them a lot. Furthermore, in case of any employee quit the job still his knowledge is retained and stored which is amongst the promising benefits it provides. Apart from the benefits codification provides there are some hurdles and drawbacks like it is not possible to codify each and every aspect of knowledge, so therefore while codifying some useful aspect might be missed out. Further, codification requires extra time and employees might not be willing always to involve in codifying knowledge. Therefore, organization needs to create awareness in their employees by motivating them to involve in codifying knowledge [57]. Further, there is a need of knowledge culture to be created through training employees, giving rewards and creating trust among employees so that everyone can participate equally and appropriately.

3.4.2. Personalization Strategy

In this strategy for managing knowledge organizations used to rely on person to person interaction i.e. contacting the relevant person directly who has relevant knowledge [57]. In comparison with codification, this strategy allows personnel to find the knowledge easily by contacting the competent person i.e. does not requires looking for documents. Further, it saves time but its limitation is loss of useful knowledge when the knowledge owner leaves the organization [57]. Further, it also has limitation of understanding the knowledge of others due to language difference, terms used and due to tacit factor present with knowledge. Additionally, sharing tacit knowledge in words is very hard so therefore thorough and deep understanding is required for it.

At last, the challenge is not to choose a strategy for managing knowledge but is the availability of relevant, appropriate knowledge at right time. This can be made possible by use of knowledge maps which is intended to help in finding the relevant knowledge at right time. For example, use of document management tools i.e. Microsoft Share Point and competence management tools i.e. Knowledge Mail, Expert Networks can help in this regard respectively [58, 59].Moreover, knowledge map is the best way to capture and share knowledge in organizational contexts because it's like a geographer's map which maps where you are i.e. identifying intellectual capital and helps in organizational learning and in making you aware of upcoming threats or opportunities [73].

3.5.　　Knowledge Creation

Knowledge creation is a continuous and dynamic process which increases with passage of time due to learning and gaining more experience through sharing and interacting with each other [60]. Further, knowledge can be created via conversion between tacit and explicit knowledge respectively. This conversion can be from tacit to explicit, tacit to tacit, explicit to explicit and explicit to tacit [47, 60, 61] as shown in Figure 05. Moreover, creating relevant and productive knowledge can be made possible through taking care of two elements namely: knowledge repository or competence and individual commitment or ability to share or gain knowledge respectively. Additionally, among these two elements individual commitment is the most important one and plays a vital role because individual commitment or ability creates knowledge repository possible by storing explicit knowledge in it but not the vice versa [60].

In the context of this thesis RE is considered to be human intensive activity which requires a lot of discussion and communication for reaching on consensus. Further, during discussion and communication on requirements among teams inside an organization or between offsite teams always lead to conversion of one form of knowledge to another. Besides, for requirements understanding socialization can take place when members of different sites discuss and share their experiences about some issue. In addition, this sharing of knowledge about the requirements could be the knowledge of people, culture, standards of organizations, knowledge of product and so on. Likewise, combination can take place when someone post a requirement problem on a discussion forum and other members come up with new ideas and solutions for the problem. Moreover, the aim of this study is to overcome/reduce requirements problems in GSE which in our opinion is possible through sharing knowledge of people, product, culture, sharing experiences, knowhow, making knowledge available to everyone and so on through the four process of knowledge creation namely socialization, externalization, internalization and combination.
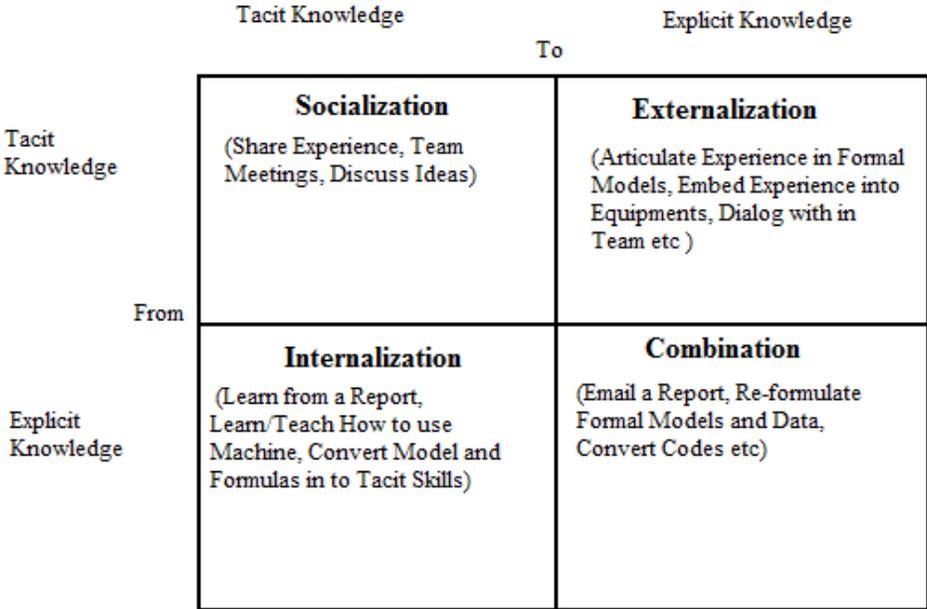
Figure 05: Knowledge Creation Processes (Modified) [47, 62, 64]

3.5.1. Socialization
The knowledge which is created by converting tacit knowledge to tacit knowledge between individuals through sharing experiences and the process is called as socialization. Further, in this process individuals try to gain experience and learn know how through observation, imitation and practice e.g. training and showing how to operate a machine [47, 62, 74]. In socialization process tacit knowledge i.e. mental models, technical skills are mainly shared and therefore mainly focused on communities and collaboration i.e. social interaction. Moreover, as the aim of tacit knowledge is to learn and gain experience from others, so therefore knowledge is created by learning during discussions, meetings, training and team work [47, 63, 64,62].

3.5.2. Combination
The knowledge which is created by converting explicit knowledge to explicit knowledge between individuals or group by integrating or reformulating the existing explicit knowledge in to a new is called combination [60, 74]. Combination can take place as a result of arranging the existing knowledge repositories by adding/sorting or categorizing the

repositories or enhancing the search criteria by subject. In addition, the aim of combination process is to collect all of the distributed knowledge and store it into one place in a structured way. Moreover, the individuals or groups transfer and share knowledge through email, meetings, telephonic conversations, documents, and discussions [47, 64].

3.5.3. Externalization

The knowledge which is created by converting tacit knowledge to explicit knowledge between individuals or groups by clearly articulating is called externalization. Further, it is impossible to fully convert tacit knowledge into explicit because there are always some aspects of knowledge which cannot be made explicit in full. As Polanyi [47] said that "we can know more than we can tell" so therefore it is hard to express and convert tacit knowledge into explicit knowledge in full. Likewise, tacit knowledge is deeply rooted in actions and it is very hard to express in words [65]. Further, tacit knowledge can be expressed through use of metaphors and therefore metaphors play a vital role in externalization process [47, 74]. Additionally, in order to increase the degree of explicitness of knowledge when converting from tacit to explicit first understand it and then transfer it so that everyone can easily learn and can then be codified e.g. discussion or dialog with other or when writing an instruction manual [64, 63, 62]. Moreover, externalization takes place through documenting individual's thoughts, expert opinions, learned stories and then making it accessible and available to all members through some shared repository [66].

3.5.4. Internalization

The knowledge which is created by converting explicit knowledge to tacit knowledge is called internalization [47]. In this process individuals reads the explicit knowledge stored in repositories in the form of documents, manuals and past stories which helps them to increase their experience. Further, internalization helps individuals to gain re-experience because they increase their experience from what others learned previously. Additionally, this is not an easy task as they have to deal with large repositories but in order to cope with it they need to read repositories from multiple sources [64]. Internalization is somehow the processes of learning by doing because individuals read, absorbs the knowledge and then apply/practice the knowledge e.g. learn from a report [63]. Moreover, internalization occurs very rapidly across organizations because more individuals are involved in this process who reads repositories, gain experience from past lessons which then enhance and increase their skills and competence [60].

3.6.　　　Communities of Practice (CoP)

According to Wenger, "Communities of Practice (CoP) are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis". The most important asset of organization is knowledge and tacit knowledge is very hard to share and understand but communities of practice provide a good ground for sharing and transferring tacit knowledge [75]. Further, communities of practice are specific and unique i.e. common practices and procedures compared to virtual networks of people. Additionally, communities of practice can not only reside inside an organization but can also exist across boundaries like geographically distributed organizations [56]. Further, for geographically distributed organizations need a shift from in walls community of practice to virtual communities of practice because it helps them to increase interaction, knowledge and information sharing through Information Communication Technology tools (ICT) [67].

A CoP has three main characteristics on the basis of which it is considered important for organizations; common knowledge and practices, shared identity and common values [7]. Besides, the study of Rus et al [9] shows that the most common and easy way to share knowledge and experience is making use of communities. Furthermore, in CoP knowledge communication, share and transfer is easily done because the community is specific i.e.

narrow and also it is easy to contact the relevant expert people regardless of their location [56]. Moreover, CoP helps organization to share knowledge, create knowledge, reuse knowledge i.e. sharing experiences and learning from past stories, increases collaboration and interaction by connecting employees, creates a shared context and stimulate learning process.

In this study CoP is seen to be one of the most important KM practice because CoP can be used for overcoming requirements understanding problems in GSE. Besides, the role of communities is important in a sense that people are linked with each other, they have common work and practices and they share their relevant knowledge which is very useful in requirements understanding. E.g. If somebody having problems in requirements related issues then communities can play a major role by providing easy access to relevant expertise, repositories and gaining benefits from different experienced personnel. Moreover, in GSE CoP can be useful in finding relevant expert or document rather easily because it is not an issue to solve a problem but finding relevant past knowledge and experience personnel in no time is a challenge.

3.7. Document Management (DM)
In KM perspective all those documents which an organization produces to store knowledge is explicit knowledge, which helps them for recreation of new knowledge by reformulating and broadening its scope and also helps them to find the originator of the knowledge. Likewise, DM enables organizations not only explicit to explicit knowledge conversion i.e. by interpreting and getting ideas from stored explicit knowledge and then broadening its scope by applying it in a different context but also helps organization in tacit to explicit knowledge conversion through expert identification i.e. by finding a relevant expert through authorship of the document and then solving problem through his experience and suggestions [58].

In this study DM is seen as an essential component of KM because an organization needs to store knowledge in a structured way and it specially becomes more important when the size of organization is large. Further, the common needs are identifying and accessing the correct and exact document in less time from anywhere, searching and editing the relevant document easily and last but not least identifying the author of the document. Additionally, DM is more important for geographically dispersed organizations in order to enable them to share their experiences and knowledge across all organizations within no time which will help them to solve problems easily, know-how of each other easily and create new knowledge for future use [58, 64]. Moreover, DM enables organizations to summarize, store, categorize/indexing, edit, secure access from anywhere and expert identification easily which in turn leads to creation of new knowledge [9, 58, 64]. Some common examples of DM systems are Microsoft Share Point, Collaborative Document Management Solution (CDM), Documentum 5, and Lotus Discovery Server [58].

3.8. Competence Management (CM)
Like DM, CM is also the essential component of KM because organizations are always in need for finding relevant expert personnel who have knowledge for the specific problem to be solved [58]. Further, it is not possible to store and convert fully knowledge into explicit knowledge because as Polanyi said "we can know more than we can tell". In addition, tacit knowledge is about the experiences people have in their minds which sometimes become difficult to articulate in words and is deeply embedded in actions of the knower's [47]. Additionally, CM is mainly focused towards tacit knowledge of the organization i.e. knowledge stored in minds of experts whereas DM is mainly focused towards explicit knowledge stored in repositories [58].

Most of the times organizations have the relevant knowledge and competence i.e. experts but identifying and accessing them is not easy because employees are unaware of it and also it is

too much time consuming. In order to overcome this issue organization need to have knowledge maps through which it becomes easy who has the relevant knowledge and where the knowledge is stored [58]. Further, through knowledge maps it then becomes easy for an organization to have these four processes namely; competence identification, competence assessment, competence acquisition and competence usage respectively [69]. In addition, all these four processes are aimed towards who knows who, who knows what, to appropriately assign tasks to the relevant personnel based on their experiences, to hire relevant new people if needed and to arrange training programs for increasing knowledge and competency. Moreover, CM tools are very important for large organizations and especially for distributed organizations because in this way problem are solved easily by identifying and accessing the relevant person within no time. Some common examples of CM tools are Skill-Scape, Knowledge-Mail, Skill-View Enterprise 5.0 and Path-lore Skills Management System [58].

In the context of this thesis CM is also among the most important practice of KM because for resolving requirements understanding issues in GSE relevant expert identification and utilizing his experiences is very important. Further, proper CM can play a vital role because organization has experts who have past experiences, knowhow of culture, people, and product and so on which can be very useful for resolving requirements understanding issues.

3.9.   Summary of the Chapter

The aim of this chapter was to answer the first research question i.e. "What is the current state of practice of KM?" This chapter contributed to answer the research question in a number of ways. First of all an overview of KM has been presented with its importance in GSE. Secondly, by giving an overview of KM helps the intended readers to build up their knowledge base gradually to the field of KM. In addition, the overview particularly highlighted concepts, necessity and importance of KM in GSE. Besides, as in globally dispersed software organization KM helps to effectively manage who knows what and who knows who which helps in learning, problem solving and innovation of organizations. Further, as the focus of authors study is only requirements understanding in GSE, therefore, KM can be used to overcome requirements understanding issues by sharing product knowledge, culture knowledge, creating trust which helps in team building, use of CoP, identifying expertise and proper document management i.e. easy access to relevant knowledge.

4 INDUSTRIAL INTERVIEWS

4.1. Company A

4.1.1. Introduction of Company

Company A is an ISO 9000 certified, globally reputed and well known Swedish organization working in telecom sector founded in 1876. Further, it provides telecom and mobile products and services to approximately 140 countries across the world. Besides, as more than 1000 networks uses Company A products so therefore 40 percent of all mobile calls are made through their products. Moreover, due to Company A's success factor it is amongst one of the few organizations globally which provides and offers end-to-end solutions for all major mobile communication standards and focuses on promoting open standards and systems.

4.1.2. Introduction of Interviewees

The authors conducted two interviews in Company A with two different persons because both of the interviewees were specifically working in field of RE and their expertise. The first interviewee was person X who holds bachelor degree from Hogskola Karlskrona. Person X works as a Technical Product Manager (TPM) in company A and has thirteen years experience. Person X is directly involved in RE activities and his main responsibilities included initiating requirements, negotiating, involved in decision making, checking requirements fulfillment and requirements conflicts resolution. The second interviewee was person Y who has Higher Secondary Education and some university education. Person Y also works as a TPM in Company A and has approximately eleven years of experience in Telecom companies. As Person Y works in the same company as Person X with same position so therefore they have the same tasks and activities in RE.

4.2. Company B

4.2.1. Introduction of Company

Company B is a Sweden based company founded in 1998. It is an independent company and serves the global telecom sector. Further, it develops both bespoke and market driven products for its customers. Moreover, Company B mainly develops and license user interface platforms for smart phones based on Symbian operating system to the world leading mobile manufacturers.

4.2.2. Introduction of Interviewee

The interviewee Person Z is working as a Supplier Manager and has three years experience at Company B. Before this position Person Z was working as a Software Quality Engineer. Further, Person Z has done Master in Software Engineering and Licentiate in Software Engineering and Process Improvement from Blekinge Tekniska Hogskola (BTH), Sweden. Although, Person Z is not involved directly in RE activities but he is quite competent and has a blend flavor of experience of both academia and industry. Moreover, he has deeper insight and know how of RE activities carried out in his Company B.

4.3. Interviews Execution

As discussed in research methodology (See Section 1.7), that the authors have conducted semi-structured interviews because it helps and enables interviewers to ask questions according to the interest of discussion. For this purpose open-ended questionnaire was designed for conduction of interviews. Further, the questionnaire was tested and validated by the authors in order to eliminate the conclusion validity threat (See Section 5.7.4). The complete questionnaire has been given in Appendix B.

The interviews at both companies i.e. Company A and Company B, were conducted by the authors, who had enough interviewing experience and training by studying research

methodology course and other courses during their Master's study. Besides, Fowler [94] also mentioned in his book that training and experience is important and plays a vital role while conducting an interview.

Before the conduction of interviews, all the interviewees were informed and all the project related stuff were sent to them in advance in order to give them a background knowledge, make them cooperative and comfortable during interview process, as suggested by Fowler [94].

As authors have conducted three interviews in two different software companies, therefore the interviews sessions were allotted by the interviewees according to their own suitable and flexible dates and time. According to Fowler [94], interviewers should have flexible schedules so that interviewee (s) can make an appointment at any time suitable to them. In this research study all the interviews sessions were given by the interviewees which were quite flexible and comfortable for both concerned parties. The interviews sessions given by interviewee X and interviewee Z were 2 hours while interviewee Y given us 1 and half hour.

4.4. Interview Analysis

The intent behind conducting industrial interviews were to map industrial and academia challenges of requirements understanding in GSE and to know the severity level of those challenges identified by Carmel [21] in industries. According to Carmel [21], there are five GSE challenges which have impact on requirements understanding (see Section 2.4.1.1) but the authors also succeeded to identify and map the time zone difference as a sixth challenge. Further, the result of interviews conducted in both industries does not differ so much from each other except the severity levels of each identified challenge. Besides, the difference in severity levels of each challenge is due to size of organization, culture of organization, setup of organization and number of projects and its complexities. Moreover, as shown in Table 04 depicts the severity level of each identified challenge of requirements understanding due to GSE in both Company A and Company B.

Table 04: Challenges of Requirements Understanding in GSE (Company A & B)

Challenges	Company A	Company B
Culture Differences	🔴	🔴
Geographic Dispersion	🔴	🔴
Loss of Communication Richness	🔴	🔴
Co-ordination Breakdown	🔴	⚫
Loss of Teamness	⚫	⚫
Time Zone Difference	🔴	⚫

🔴 → Depicts Major Issue

⚫ → Depicts Minor Issue

From literature review the author's have identified several challenges of requirements understanding in GSE are summarized in Table 01 (see Section 2.3.2). Further, in order to get a better understanding and insight of these issues, views of Company A and Company B are summarized in Table 05.

Table 05: Views of Company A & B on Identified GSE Challenges from Literature

Sr. No	Ref. No	Challenges Identified from Literature Review	Views of Company A & Company B
1.	[2, 21, 25]	**Culture Differences:** Different ways of thinking, solving problems, attitudes, commitment, language and style of communication and so on.	Culture is not the way of celebrating Christmas but rather it's a way of thinking and solving problems. It's hard to reach on consensus due to lack of understanding and commitment.
2.	[21, 26, 29, 30]	**Geographic Dispersion:** Geographic dispersion is like "out of sight out of mind" which has caused several problems like trust, motivation, less co-ordination, miscommunication and control.	Misunderstanding of organizational framework, misunderstanding requirements and increases rework.
3.	[20, 27, 30]	**Loss of Communication Richness:** As distance increases communication becomes more problematic and challenging, availability of technology infrastructure, lack of closer interaction, mode of communication and lack of face-to-face interaction.	Lack of face-to-face meetings, availability and use of appropriate media, less co-ordination, less informal communication and culture differences.
4.	[21, 29]	**Co-ordination Breakdown:** It's hard to meet personally everyone i.e. lack of interaction and lack of intense communication.	Lack of close collaboration, different units dispersed far from each other, lack of frequent visiting.
5.	[21, 24]	**Loss of Teamness:** Lack of face-to-face meetings and hence trust is lost, culture diversity, difference in organizational standards, policies and development processes and language barriers.	Trust is the major issue, motivation, awareness, culture differences and lack of frequent communication.
6.	[20, 23, 29]	**Time Zone Difference:** As distance increases time zone difference increases which in turn causes many problems like arranging meetings, loss of intense interaction and co-ordination and mode of communication.	Discussing urgent issues and problems when needed, delay in response and increases rework due to unresolved issues on time. Further, team work is necessary to negotiate issues between different units at the same time.

Besides, as the authors study is based on Carmel centrifugal forces (see Section 2.4.1.1) therefore the detail views of interviewees on the impact of GSE challenges on requirements understanding is discussed separately below with the practices and solutions used for it in both industries.

4.4.1. Culture Differences

By analyzing all of the interviews in both companies have enabled the authors to know the opinions on culture differences in industries. Company A thinks that culture is not the way people celebrates their holidays but it's rather the way of thinking and solving problems that makes the difference. The interviewee X at company A claimed as "*Culture is not the way of celebrating Christmas or not the way of going to school but it is rather setting up the ways of working when you have a distributed organization*". They think that culture difference can not only exist between countries but can also exist between cities within the same country. The interviewee Y at company A and interviewee Z at company B have same opinions about culture difference. They believe that the main culture differences are; understanding each other and fulfilling and understanding what the commitment means. The interviewee Y at company A quoted about understanding each other as " *if I say like this and he answers like that then he might not mean that because that is the way their culture is , they say 'Yes' but they have not understood*". Furthermore, the interviewee Y also considered language as one of major issue when communicating each other properly and especially for requirements. Likewise, interviewee Z quoted on commitment and trust as "*we once had a commitment with a supplier and they agreed to accomplish in six weeks but when the deadline reached we asked what you have done? And they said we have not started yet. So this is the culture difference. We did not suspect, it will happen but from their side it's normal to do so*".

Even though both companies have little bit different perceptions about culture difference but both of these companies thinks culture difference as a major issue when comes to requirements understanding. Further, both of the companies believes that RE is more human intensive activity therefore know how of culture and people can not be neglected. Therefore, culture has more impact on RE activities as compared to other activities in SDLC. Besides, if we take the issue of language and understanding each other in culture difference e.g. when a Software Requirements Specification (SRS) is written at one site but the other site will not be able to fully understand it. The reason being is it is hard to express every thing in words which is due to tacit nature of knowledge. Furthermore, tacit knowledge present with each requirement is also in the form of knowing and understanding each other context.

Both of the companies in past did not give more attention to the problems aroused in requirements understanding due to culture differences. They thought that it created more problems than rewards. They are now focusing and considering this issue up on the table. Furthermore, they think that culture difference can be reduced with the help of gaining knowledge of people, culture and product through intense communication and collaboration, some brief presentations about product, people and culture before starting a project, frequent meetings, frequent visiting when needed, informal discussions, trainings, liaisons and job rotations as summarized in Table 06.

Table 06: Views & Solutions of Culture Differences (Literature & Interviews)

Sr. No	Challenge Identified in Literature	Solution in Literature	Views of Company A & Company B	Solution in Company A & Company B
1.	Different ways of thinking, solving problems, attitudes, commitment, language and style of communication and so on [2, 21, 25].	Face-to-Face Meetings [27, 24], Training and Common sense [27], Terminology [27], Language trainings and sharing culture issues and customs [27], Trust [26], Encourage social interaction (Motivation) [26].	Culture is not the way of celebrating Christmas but rather it's a way of thinking and solving problems. It's hard to reach on consensus due to lack of understanding and commitment.	Intense knowledge sharing (people, culture, and product), Introduction of team members (Kick-off meetings), meetings/visiting, Formal discussions, Trainings, Liaisons and Job rotation.

4.4.2. Geographic Dispersion

Both of the companies have approximately same views and opinions about geographic dispersion problem. Further, they think that geographic dispersion has not only disadvantages but advantages as well which drive us in going off shore. In addition, some of the advantages of geographic dispersion are availability of talented and competent people because it's easy to recruit outside, gaining lead time, close to market and less use of resources which in turn saves budget. Likewise, geographic dispersion has caused so many problems like trust, misunderstanding organizational framework, hard to reach on consensus due to culture difference, misunderstanding of requirements, time difference and increases rework due to lack of understanding each other's commitment.

The major issue being experienced in both companies due to geographic dispersion is lack of understanding each other in time. Furthermore, the interviewee Z quoted "*If I am wrong tell me how I am wrong, give me some suggestions etc*" and detection of disagreements because it has impact on requirements understanding by in large. Likewise, when solving requirements issues it is necessary to understand each other what is individual thinking, meaning and perception about the issue. The reason being lack of understanding each other is mainly due to culture difference, language barriers, trust and commitment. Besides, the interviewee Y told us that requirements misunderstanding have impacted their projects by increasing rework and quoted "*I did not mean it; I was thinking it will be like this and this*". Moreover, for Company A time difference has also been seen as a challenge in geographic dispersion because when time zone differences are large it's hard to communicate and negotiate requirements issues well in time.

Despite the fact that geographic dispersion has challenges but both companies' thinks that the more you know each other the more you will be able to solve problems and issues. Further, this know how can be about culture, product, organization and people. Besides, knowledge sharing is the one way which makes it possible. Likewise, frequent communication, discussion forums, collaboration and co-ordination are the other ways to over come geographic dispersion as summarized in Table 07. Moreover, the interviewee Z

focused and quoted on frequent communication and increments as "*Don't wait for big bang keep on asking*".

Table 07: Views & Solutions of Geographic Dispersion (Literature & Interviews)

Sr. No	Challenge Identified in Literature	Solution in Literature	Views of Company A & Company B	Solution in Company A & Company B
2.	Geographic dispersion is like "out of sight out of mind" which has caused several problems like trust, motivation, less co-ordination, miscommunication and control [21, 26, 29, 30].	Face-to-Face (Kick-off) Meetings, Audio and Video conferencing, Email and Voicemail, Internet and Intranet [26], Centralized Bug Reports, Know-how of rules and policies of countries [24].	Misunderstanding of organizational framework, misunderstanding requirements and increases rework.	Intense knowledge sharing (culture, people and product), Frequent communication (Formal and Informal), Discussion forums, Increments (Modularization), Increase collaboration and co-ordination.

4.4.3. Loss of Communication Richness

Communication is considered as a challenging and important issue for both companies. As in GSE its hard and expensive to travel for each and every issue therefore organizations use to communicate mainly through telephone, emails and video conferencing.

Both of the companies stressed and focused on visual representations of requirements problems because it is not enough to discuss only on telephone due to the fact that you do not see what other one sees i.e. you can not locate/pinpoint to the issue. Likewise, language is also considered as a barrier because it is hard to express everything, to speak fluently and to make other person clear about the issue. Besides, the problems with emails when communicating are; hard for readers to understand the context, loss of relevant details and taking assumptions which can lead to misinterpretations of requirements. In addition, loss of communication richness is also due to less communication and meeting face to face. The interviewee Z quoted on importance of communication as "*I used to stress to call at least once a week to other units even if it is not really important to build a culture so that talking with each other becomes easy. They should not think twice IS IT OK to call Mr.XYZ they should just call because it solves problems much easily*" and interviewee Y claimed on necessity of meeting face to face as "*It is important to meet face-to-face at least once because it is one thing to call someone that you have met with and talk about problems and issues. It is totally different thing to call that person if you have never met him/her*". Moreover, both companies thinks that culture difference has also impact on the richness level of communication because in some countries it is normal to say "*Yes*" even if he/she have not understood the issue in full due to shyness, not to loose their faces and so on.

As RE is human intensive activity and needs more and more communication for resolving issues therefore both of the companies uses only audio as a medium for requirements communication. In addition, company A has video conferencing setup but it was quite strange that they do not use it at all. In author's opinion, it is good to have not only visual representation of requirements but it also enables to talk face to face which helps in

understanding each other and resolving issues. Although, company B do not have setup for video conferencing but planning to have it in near future and they considered very important for requirements communication, discussing face to face, gaining trust and resolving issues. Besides, both of the companies also have some specific tools for requirements, discussions forums and informal communication for resolving requirements issues. More specifically they preferred the use of visual representations of requirements and video conferencing. Moreover, they also have frequent visits to meet face to face which helps in knowing about each other, creating trust and motivation as summarized in Table 08.

Table 08: Views & Solutions of Loss of Communication Richness (Literature & Interviews)

Sr. No	Challenge Identified in Literature	Solution in Literature	Views of Company A & Company B	Solution in Company A & Company B
3.	As distance increases communication becomes more problematic and challenging, availability of technology infrastructure, lack of closer interaction, mode of communication and lack of face-to-face interaction [20, 27, 30].	Informal communication via email, Net meeting and Tele [24] and video conferencing [27, 20], Splitting the projects into smaller independent units (modularization), Face-to-face meetings, Kick-off meetings [27], Liaisons, Intranet, Travel [24].	Lack of face-to-face meetings, availability and use of appropriate media, less co-ordination, less informal communication and culture differences.	Visual representation of requirements (Visualization), Face-to-face meetings, Discussion forums, Informal communication (Email, Telephone and Chat) and visiting.

4.4.4. Coordination Breakdown

As the geographical distance increases it becomes more and more difficult for organizations to coordinate with each other due to several reasons like lack of communication, lack of collaboration, expert identification and so on. Further, both companies are facing this issue and trying to reduce it with the passage of time. Beside, both of the companies strongly believe that coordination breakdown has impact on requirements understanding and occurs mainly due to lack of frequent communication both formal and informal, lack of collaboration, identifying relevant experts, time difference and lack of standardization and so on. Moreover, as requirements conflicts are resolved through close coordination therefore it is necessary to overcome coordination breakdown. Likewise, for requirements understanding to reach on consensus and agreement requires intense communication and negotiation therefore close coordination is necessary for it as well.

Both of the companies have approximately same opinion about ensuring coordination. For close collaboration they use to have frequent informal communication i.e. chat and formal communication through telephone and email. However, they also have discussion forums and Intranets in use. Furthermore, Company A have specific requirements forums i.e. central repository where they discuss, elaborate, comment, share ideas about requirements in order to understand and embrace requirements. Besides, Company A for making communication easier and finding an expert easily they also have specific competence management systems. Moreover, both of the companies are now focusing and shifting towards communities

because it helps in knowing each other and solving problems easily which ensures coordination as summarized in Table 09.

Table 09: Views & Solutions of Coordination Breakdown (Literature & Interviews)

Sr. No	Challenge Identified in Literature	Solution in Literature	Views of Company A & Company B	Solution in Company A & Company B
4.	It's hard to meet personally everyone i.e. lack of interaction and lack of intense communication [21, 29].	Frequent communication [29], Low coupling (modularization), Task distribution, Incremental milestones and Repository of bugs [24].	Lack of close collaboration, different units dispersed far from each other, lack of frequent visiting.	Frequent communication (Formal and Informal), Intranets, Discussions forums and CM systems.

4.4.5. Loss of Teamness

It is quite obvious that as teams are dispersed geographically so therefore there are several reasons which affects the teamness across different units. In both companies the authors observed that they are facing problems with loss of teamness not directly on requirements understanding but by in large on other phases of project. By closely observing and analyzing both companies opinions the authors have identified that as there is lack of close interaction and intense communication between different teams so therefore trust is lost. Furthermore, lack of interaction is also due to difference in culture and language because people hesitate to call or discuss with other units due to language barrier. In addition, other reasons being indentified for lack of interaction are; frequent visiting, its hard to identify the relevant expert, understanding each other, informal discussions and on time availability of experts. Besides, motivation and awareness is also lost when expert are not available at time i.e. when problem has aroused which in turn causes delay.

Both of the companies believe that although loss of teamness has not so much direct impact on requirements understanding but due to the fact that key to success is team work. Besides, for requirements understanding continuous discussion, negotiation, interaction and communication are needed which are lost when teamness problem arises therefore it can not be neglected. In both companies teamness is not considered as a major issue. For ensuring teamness they use the good approach of task modularization which helps them in reducing dependency on each other. Further, they have close collaboration and frequent formal and informal discussions to ensure interaction. In Company A for creating trust and motivation they have frequent meetings, short introduction before starting of a new project and rewards based on achievement of tasks. They also have standard competence management systems where it is easy to find an expert and thus helps in solving problems and reducing loss of teamness issue. While in Company B for creating trust they usually have rewards and some dinner parties in order to meet face to face and to know each other, discuss issues, and motivate each other. Besides, each unit has separate local manager which is responsible for team work and helps in expert identification when needed. Moreover, both companies stressed upon coordination among team as one of the most important factor for making consistency in flow of work and ensuring teamness as summarized in Table 10.

Table 10: Views & Solutions of Loss of Teamness (Literature & Interviews)

Sr. No	Challenge Identified in Literature	Solution in Literature	Views of Company A & Company B	Solution in Company A & Company B
5.	Lack of face-to-face meetings and hence trust is lost, culture diversity, difference in organizational standards, policies and development processes and language barriers [21, 24].	Kick-off meetings, Trust building [26, 20], Define the product, video conferencing, Face-to-face meetings, Trainings [26], Define the project [26, 24] and common work products (Terminologies) [24].	Trust is the major issue, motivation, awareness, culture differences and lack of frequent communication.	Task modularization, Close collaboration and interaction, Frequent formal and informal discussions, Frequent meetings, CM systems, Rewards, Separate technical expert for expert identification.

4.4.6. Time Zone Difference

In globally dispersed teams time zone differences exist and increases when it comes between two continents. In both companies time zone difference is considered as an issue but Company A thinks it is a challenging issue because it not only affects team work but also causes delay. Company A thinks that one of the reason due to which organizations adopt offshore is to have round the clock development which in their opinion is wrong and claimed as "*Time difference could be beneficial for us, because we at location X could write the requirements specifications and then we can just send it and a few hours later the team at location Y start working on it and implement it, but I think it is a lie because it does not work that way. In some cases it might works well but in other it will not because what we are doing requires team work. Besides, its not just to write the requirements and then hand it over to someone and believe that person will understand it as you understood it and implement in that way*". Besides, Company A believes that due to time differences it is always hard to communicate and discuss issues at the same time.

Company B preferred the use of asynchronous communication like email as the best solution because through email one can directly send the problem in written form to the relevant person. Besides, it has also some drawbacks like delay and misunderstanding the context of issue and so on. While in Company A they preferred the approach of communities and email for overcoming/reducing the impact of time zone differences as summarized in Table 11. Moreover, in authors opinion modularization of tasks in such a way so that closer time zones have much dependency on each other and larger time zone difference have less dependency on each other which will help in communicating each other easily irrespective of time constraints.

Table 11: Views & Solutions of Time Zone Difference (Literature & Interviews)

Sr. No	Challenge Identified in Literature	Solution in Literature	Views of Company A & Company B	Solution in Company A & Company B
6.	As distance increases time zone difference increases which in turn causes many problems like arranging meetings, loss of intense interaction and co-ordination and mode of communication [20, 23, 29].	Asynchronous communication media like email or voice mail [25, 20], Awareness of time constraints of both sides [25] and Synchronous communication [20].	Discussing urgent issues and problems when needed, delay in response and increases rework due to unresolved issues on time. Further, team work is necessary to negotiate issues between different units at the same time.	Email and Communities.

4.5. Summary of the Chapter

The aim of this chapter was to answer second research question i.e. "What are the challenges of requirements understanding in GSE?" The answer of this research question has been addressed in this chapter only from industrial interviews. Besides, this chapter contributed to research question in several phases simultaneously. Firstly, the authors found the severity level of each GSE challenge and its impact on requirements understanding. Secondly, to map GSE challenges of requirements understanding identified in literature with industries. Besides, industrial solutions i.e. practices and tools used for reducing the impacts of GSE challenges on requirements understanding were also discussed. Furthermore, the authors also found that time zone difference is also an important issue in GSE. Moreover, the comprehensive interview analysis shows that both companies have approximately same views, opinions and suggestions for reducing requirements understanding issues faced in GSE.

5 DISCUSSION AND VALIDITY THREATS

Knowledge management is considered to be the most important asset of an organization. Besides, it plays an important role in efficiently sharing, creating and storing knowledge for future reuse. Furthermore, the importance of KM can not be neglected for globally dispersed teams because GSE has several challenges (see Section 2.3.2) due to which requirements understanding issues occur. Moreover, as the authors study is to supplement Carmel solutions (see Section 2.4.1.2), therefore in following sections a comprehensive discussion has been made on how KM helps in reducing requirements understanding issues faced in GSE as summarized in (see Appendix A).

5.1. Collaborative Technologies

According to Carmel [21], collaborating technology can help to resolve requirements understanding issues faced in GSE due to culture differences, geographic dispersion, loss of communication(both formal and informal), co-ordination breakdown, loss of teamness and time zone difference. However, KM can supplement Carmel solution by providing useful practices like proper competence management, document management, and socialization and so on. In GSE when teams communicate requirements are actually transferring knowledge and this process is called socialization. The study of Marwick [64], shows that socialization process can take place when team members meet either face to face or through use of some ICT tools like video conferencing by sharing and discussing ideas. It can also take place when they discuss and share knowledge through audio conferencing and telephone calls. Besides [84], the role of ICT support for KM activities/processes can not be neglected in GSE environment.

In socialization [64, 58] mostly tacit knowledge is transferred which is hard to understand. Further, it is also tacit knowledge which you are unaware of or even do not know but faced in situations i.e. this problem is similar to another one then I did like this but can you apply it here as well, but that's not until you see the problem. The interviewee Z at Company B claimed on tacit knowledge as "*humans are afraid of snakes because of its poison and horribleness but if when you have not seen a snake into wild you can't say that you are afraid of it but when you see you are afraid of*". Therefore, some visual representations of ideas are necessary to make the situation and issue more clear for better understanding and discussions. Likewise, in the context of requirements to be more clearer, put them in some context and then start discussing it. Tacit knowledge is always considered hard to express therefore the more one can discuss, the more tacitness will be reduced. Tacit knowledge has impact on requirements understanding because requirements are always misunderstood by taking different assumptions, lack of culture knowledge, misinterpretations of words, richness level of communication, lack of collaboration, understanding each other and so on. Besides, requirements are also unclear due to lack of culture knowledge which can be reduced with publishing and distributing culture, people and product knowledge on Intranets, codifying in document management system of organization and through liaison.

Likewise, the process of socialization is not only useful to reduce culture differences issues but is also useful for reducing geographic dispersion, co-ordination breakdown, loss of teamness and time zone difference issues. As in socialization [64] not only individuals shares knowledge but also members in form of groups share knowledge i.e. communities. Further, in communities all members share knowledge about same work and issues. As in communities both personalization i.e. person to person and codification i.e. documenting knowledge strategies are adopted so therefore its very useful for reducing requirements understanding issues in GSE. E.g. It can be helpful up to some extent to tackle time zone difference because if an issue arises to some one so therefore the person can not only search the solution in stored/codified knowledge of the community but can also contact the exact relevant experienced person. Besides, Company A also supported communities by

commenting that our organization is now shifting towards communities because it solves problems easily.

In GSE by making the process of socialization more easy and fluent will thereby help in reducing requirements understanding issues because, expert identification is a challenge which can be tackled through adopting KM practice of Competence Management (CM). CM helps in reducing culture difference, geographic dispersion, co-ordination breakdown and loss of teamness issues because it is not a challenge to solve an issue but the main challenge is to find an appropriate person who can help in sorting out the problem. E.g. As teams are dispersed globally and requirements which are misunderstood due to culture differences can be reduced through implementing and adopting an appropriate CM strategy. By doing so an appropriate CM strategy will let you know who can have relevant culture knowledge by visiting his/her profile i.e. previous experiences, previous trainings, and previous visits and so on.

In GSE knowledge transfer takes place when team members sends emails to each other for discussing requirements issues, posting requirements issues on requirements forums, chatting with each other for discussing requirements issues and sending requirements visually i.e. in power point, diagrammatic representation and images. In addition, all these activities lead to creation of knowledge and the processes are called externalization, internalization and combination [64]. Besides, all these three processes of knowledge creation can occur simultaneously or interchangeably. E.g. in GSE email is considered to be the most common way of transferring knowledge and discussing issues. It can reduce culture issues, co-ordination breakdown, geographic dispersion and time zone difference issues because it is easy to share and describe the knowledge in written text rather than discussing it in real time due to far flung teams and language barriers. Moreover, email can lead to process externalization, internalization and combination because a team member share experiences (tacit/explicit), providing solutions (tacit/explicit), discussing issues (tacit/explicit) thereby the other team member will read and gain knowledge which helps in understanding requirements.

Forums are also considered to be useful for reducing understanding requirements issues. Furthermore, Company A has a separate requirements forum where they used to post every sort of knowledge regarding requirements and helped them a lot for solving and discussing issues. Further, requirements forum also supports the three process of knowledge creation i.e. externalization, internalization and combination because team members post requirement issues and other team members provides solutions, comment, shares opinions and experiences which leads to creation new knowledge. In addition, requirements forums also helps in reducing co-ordination breakdown, geographic dispersion, culture issues, loss of communication richness and loss of teamness because on forums its easy to share knowledge and discuss issues. Besides, as forums are like a repository so anyone can see and find his/her relevant information which thereby helps in reducing co-ordination breakdown and loss of teamness. Likewise, as it supports in enhancing teamwork and co-ordination which thereby also reduces communication and culture issues because requirements forums acts like a one stop shop where one can find everything related to requirements. Moreover, it can have shared experiences of team members, solutions, ideas and opinions which help a lot in problem solving.

Like socialization, the three process of knowledge creation i.e. externalization, combination and internalization [64] helps in overcoming requirements understanding issues because these three processes of knowledge creation are achieved through emails, forums, chatting and visualization i.e. visually representing requirements. Moreover, as GSE teams are geographically distributed so therefore the four process of knowledge creation can not be achieved in full without use of technology. Therefore, ICT tools like video-conferencing, audio-conferencing, chat tools, intranets, forums and so on can support the four process of

knowledge creation. Besides, ICT tools support can not be neglected in GSE but the most important thing is to make use of the tools in order to increase the efficiency and productivity. Because, from interviews the authors' observed that Company A although had a proper infrastructure for video-conferencing but they did not used it at all for requirements communication and discussions. Further, the interviewee X stated that it will be good for organization to make use video-conferencing instead of only having telephonic calls or audio-conferencing because it makes a big difference when talking some one face to face. It also creates trust building, helps in knowing each other i.e. building relationship, understanding each other and especially for requirements discussions to pin point the issue.

5.2.   Telecom Infrastructure

According to Carmel [21], telecommunication infrastructure is the need of every team involved in GSE. Further, it acts like a foundation for a building. So therefore, in order to go offshore every organization must have provided and installed a reliable and efficient telecommunication infrastructure in order to collaborate and communicate. Likewise, in KM there is emphasis on need for a good telecommunication infrastructure for globally dispersed teams. In author's opinion a good telecom infrastructure acts like a backbone for GSE teams, otherwise no such activity can be carried out between teams. Furthermore, as a car cannot be driven without wheels therefore in GSE no activity can be performed without having reliable and efficient telecom infrastructure. Besides, in KM a good telecommunication infrastructure includes telephone for making calls (formal and informal) and high speed internet to support email, online collaboration (video and audio), chatting, searching and so on. It is quite obvious that a poor and slow telecom infrastructure causes delay in work, increases rework, improper communication and co-ordination in GSE teams. As Smite [87], study shows that slow and poor communication channels caused delay in work because of extra hours taken in compilation of code per day.

In the context of requirements understanding in GSE knowledge sharing and proper communication can not takes place without good support of telecom infrastructure i.e. internet and telephone. Besides, it was quite obvious that both Company A and Company B have good support of telecom infrastructure. They claimed that RE is more human intensive activity which always requires sharing and communicating knowledge over and over which is only possible with full support of reliable telephone lines and high bandwidth internet. Moreover, by having efficient and reliable support of telecom infrastructure i.e. telephone and internet can help globally dispersed teams to reduce issues of requirements understanding by collaborating, communicating and sharing knowledge and co-ordinating easily.

5.3.   Managerial Techniques

According to Carmel [21], global software teams requires motivated and responsible project management committee for the management of different activities related to projects and also people involved in these projects. To achieve this, global software managers use different techniques for the successful completion of projects. However, in GSE global managers come across different challenges like culture difference, loss of teamness, co-ordination breakdown and so on (see Section 2.3.2) along with the different activities of projects. Therefore, different solutions and techniques have been proposed by Carmel [21].

Keeping the scope of the study in mind, the authors have identified different KM solutions from literature review and industrial interviews for overcoming/reducing requirements understanding challenges faced in GSE.

RE phase is the crucial phase of SDLC because it is mostly human intensive activity. Further, requirements always need co-ordination, negotiation and discussion for resolving conflicts and ambiguities. In KM perspective this co-ordination and negotiation can be seen

and leads to knowledge sharing. Therefore, different team members dispersed geographically requires knowledge sharing directly or indirectly related to requirements. Hence to share knowledge (related to requirements), the authors have proposed different KM practices like job rotation, motivation and trust building which can help global project managers for reducing requirements understanding challenges faced in GSE.

The first KM practice which should be adopted by global project managers is job rotation because it helps in the reduction of culture difference. Further, global project managers should create a culture of job rotation among different units dispersed geographically. By doing so, employee moved from one unit to another unit can easily understand the ways of working of other unit, culture of organization, culture of people, language, and so on. On returning back to his/her own unit after serving for some specific period of time in another unit, he/she can easily understand the values, beliefs and words interpretations attached with the requirements as tacit knowledge as compared to other employees of an organization. Rus et al [9] also suggest knowledge management practice i.e. job rotation which should be adopted by global managers because it helps team members to easily share their knowledge throughout the project and organization. Therefore, authors believe that job rotation is very good practice of KM which should be considered by managers involved in GSE projects.

As discussed earlier that knowledge sharing is important among different team members of GSE therefore, global project managers should motivate employees for sharing their knowledge. In Hislop book [7], motivation is a managerial activity which is important for sharing knowledge. As most of the organizational knowledge is personal and tacit specifically in case of requirements, therefore motivation is important. Sharing of knowledge (requirements) can occur through close interaction and co-ordination which is totally based on motivation and willingness of people who have this knowledge. Further, global project managers should offer different rewards like job security and promotions to employees for motivating them to share knowledge [7] and make using of specific technologies like DM, CM, communication and collaboration tools and communities which helps in knowledge sharing. The study of Rus et al [9] shows that the team members should not only be encouraged but should also be awarded for sharing, searching and reusing of knowledge by introducing the 'reward systems' through out organization. Furthermore, rewards like job security and promotions also helps in loss of teamness because teams scattered geographically will always participate in sharing their experiences and knowledge for getting rewards. As a result the people which are part of a team just dispersed geographically will be able to share knowledge and an environment of trust building will be created by sharing views and experiences with one another.

Moreover, organizational units dispersed geographically can work like people working in collocated if the global manager assign right people to the right task. This means that authors believe that proper competence utilization in proper place is also one of the useful practices which should be considered by global project managers. For example, if an employee knows about some culture values and customs, he/she should be considered in requirements discussions whether he/she belongs to any department of the organization. By doing so the dispersed team could collaborate easily in resolving requirements understanding issues. At last but not least, motivation, trust building and competence utilization are the driving managerial techniques which can help a global project manager in reducing culture difference, co-ordination breakdown, geographic dispersion and loss of teamness.

5.4. Development Methodology

According to Carmel [21], development methodology is a map which is used as a guide by software development teams throughout SDLC. It also acts as a bridge among different team members dispersed geographically to handle different issues and challenges faced during software development. As discussed earlier that GSE is difficult especially when teams are

working in RE activities like understanding requirements in full due to culture difference, co-ordination breakdown and so on (see Section 2.3.2). Therefore, to overcome/reduce these challenges to minimal there is a need of common development methodologies along with collaborative technologies, telecom infrastructure, managerial techniques and so on, among different units of an organization.

Hence, to deal with the requirements understanding challenges faced in GSE by using development methodologies, authors have identified Electronic Process Guide (EPG) as KM solution. According to [86], EPG is a structured, workflow-oriented and a reference document to help all the participants included in a project. Every organization produce their own EPG according to their needs but authors suggest that EPG should include terms and standards used in an organization for developing projects along with the elements suggested by [86]. Terminologies and standards used in an organization can help in co-ordination breakdown along with culture difference, loss of teamness, communication richness and time zone differences among team members dispersed geographically.

Terminology helps in requirements understanding in a sense that requirements are also unclear due to terms used in one organization/unit and the other unit even do not know what really that term means e.g. if we take the example of an SRS some call it as SRS, other call it as requirements document, others call it as functional specifications and so on. Further, Company B using PReq for product requirements, if these types of terminologies are used and spread over the intranets in the form of EPG then the requirements understanding issues can easily be reduced up to some extent and understood by using same type of terminologies. Further, terminologies also help in requirements understanding which is misinterpreted often due to culture difference like language peculiarities. Therefore Smite [88] suggested terminology dictionary for coping with such types of issues and challenges which will in turn reduce coordination breakdown, loss of communication richness, loss of teamness and time zone differences. According to authors' view time zone can be reduced by using terminologies because when a team member of every unit have knowledge about terms used, then the dependency on each other and communication will be reduced.

Along with using different terminologies in software industries (in the form of EPG), standards should also be used in industries especially which are involved in GSE because it also helps in reduction of requirements understanding issues. Having multiple standards, tools and templates in different units of an organization can lead to rework or loss of requirements knowledge by converting one template or standard to another, which can in turn increase misunderstanding of requirements [92]. Therefore, authors suggest that software organizations dispersed geographically should use same standards and templates (can be in form of EPG) among all units, as a result it will reduce culture difference, loss of communication richness and so on. According to authors views, a good example could be using of standards like IEEE template for requirements documentation among different units of industries like Company A is using a standardized template throughout their units in managing and understanding requirements. Further, if different units of an organization using different documents for requirements like if one unit using IEEE template and other unit using simple MS Word document created internally by the unit, can create problems like misinterpretation, incompleteness and ambiguity in requirements. On the other hand if all units are following one standard document for requirements specification and documentation then most of the requirements problems can be reduced like misinterpretations and misunderstanding created due to culture difference, loss of communication richness, geographic dispersion, loss of teamness and so on.

5.5.   Team Building

According to Carmel [21], team work can not be built up only by providing tools and installing advance technology across different sites in GSE but one of the major role is to build a culture of trust and relationship among employees so that they can easily collaborate and coordinate.

In author's opinion as distance increases its hard to manage team work in GSE because lack of frequent sharing of knowledge among teams, coordination breakdown, trust, collaboration and differences in time zones (see Section 2.3.2). Besides, the interviewee X at Company A claimed the importance and necessity of team work for every task in GSE as "*When you are developing a product you have to really work as a team from requirements stage until the delivery of the product. Every body needs to be tight together and understanding why we are doing this? Because if a unit X who is requirements setter asks the design unit Y located at different place to build the product and the design unit does not understand anything why we are building this product? Who wants it? And so on. But the unit X i.e. requirements setter knows that the product is valuable and customer likes it very much and so on but they don't tell the design unit Y. How will the design unit be motivated? No Way! They will not be motivated in creating this and will think that unit X does not know the rationale or not willing to provide us information and so on. Likewise, the same is the case with unit Z i.e. delivery organization they need to understand Why? Therefore, every body needs to work in a team*". Therefore, for requirements' understanding in GSE team work is necessary because requirements are misinterpreted due to culture difference i.e. language and trust, lack of communication, co-ordination breakdown and lack of proper collaboration among teams.

In geographical dispersion units are located at different places or sites so therefore the informal ways of communication is not present i.e. lost. Furthermore, differences in culture have also impact on projects if you don't learn cultures then you will be having issues like we take the example of language. In addition, most of the times different cultures have different interpretations of words and values of words which causes issues. The interviewee X at Company A claimed on misinterpretations of words and values as "*An OK or Good for us might be interpreted as extremely Well done or Excellent at other site. But really what we meant you have done 75% its OK but you have to still go for the rest of 25% and then you will be having Excellent work. I think that's a typical culture difference, one has to be aware of it and also what values does a word have in one culture compared to another culture*". Besides, different culture people have different ways of giving feedbacks which might also cause to misinterpretations. Furthermore, loss of face to face communication and time difference has also impacts on requirements understanding.

Although in GSE culture has impact on requirements understanding but also lack of sharing knowledge, lack of communication (formal and informal), coordination breakdown and so on which in turn affects the team work. The interviewee X at Company A claimed and focused on importance of communication (formal and informal) for team work in GSE as "*It is true that different culture creates problems in understanding requirements but one can not just generalize and say that in country X we have gigantic problem because of the culture, the problem could be the same if the activities were done in the same country but in different cities. No matter where in the world, if you break out for instance a development unit from a site and place it somewhere else you will for sure lose the informal discussion but possibly also the quick and short follow up meetings to secure that expectations are meet. I think this is one of the major causes for problems when distributing your organization*".

In author's opinion, for building a cohesive team work increase the socialization among different units. Besides, Smite [87] study shows that poor socialization affects coordination and collaboration among team members working in GSE. In addition, socialization can be achieved through visiting (meeting face to face), frequent sharing of knowledge, intense communication (formal and informal), kickoff meetings (introduction of team members),

trainings (culture and language) and so on. Besides, by ensuring socialization a culture of trust and motivation will be built among employees which are the pivot elements in team building.

In GSE visiting/face to face meetings and kickoff meetings can play a vital role in reducing culture issues, geographic dispersion and loss of teamness issues faced in requirements understanding in GSE. Besides, Moe et al [85] study shows that organization needs to spend some money on arranging one or more face to face meetings because it helps in creating trust which helps in team building. Because, meeting with each other helps in knowing each other, culture, problems are solved easily by discussing face to face, helps in knowing the status of work and organization helps in increasing trust and motivation among team members. In addition, meeting face to face is also considered to be the pivot role in the process of socialization because it creates trust and increases motivation. Moreover, visiting and kickoff meetings helps in making team work because they know each other and thereby can easily share knowledge and discuss issues. Furthermore, the interviewee Z at Company B claimed the importance of visiting for team work and therefore they have some dinner parties to buildup relationships and to increase trust. Besides, they also have rewards for motivating employees and creating trust. Likewise, the interviewee Y at Company A stated that they used to have kickoff meetings about people, product and culture.

As units are dispersed far flung from each other therefore training is necessary for team members. Besides, Smite [90] shows that training is necessary for culture understanding, creating trust and awareness among team members. Further, as requirements are also misinterpreted due to differences in culture therefore training of culture and language is necessary for team members. It also helps in making good relationships, trust and awareness among team members which boost the team work. Furthermore, the role of liaison or brokers can also help in bridging culture issues, knowing each other, sharing knowledge, problem solving, helps in explaining the interpretations of words and culture values. In addition, the role of liaison/brokers and training can not be neglected in the process of socialization because the more one can share knowledge of culture, people, product and each other the more it will increase socialization and thereby reducing requirements misinterpretations issues. Moreover, the interviewee X at Company A claimed as "*in order to overcome culture issues learn more about cultures, product and each other through some liaisons/guide who can help out in knowing about cultures and frequently sharing of knowledge*". Likewise, the interviewee Z at Company B claimed that they have Single Point of Contact (SPOC) persons for helping in translation and communication and also have assigned a responsible technical person who helps in problem solving and if he can not solve a problem then he contacts to other relevant person.

As distance between sites increases it is always hard for team members to communicate and share knowledge efficiently. Besides, frequent sharing of knowledge helps in socialization because of knowing each other, status of work and discussing problems easily. In addition, the interviewee X at Company A claimed the importance of sharing knowledge as "*it does not matter where in the world you are always share and communicate knowledge because it helps in problem solving i.e. frequent communication because it helps in problem solving*". Besides, the interviewee Z at Company B claimed the importance of frequent informal communication i.e. telephonic call as "*I used to stress to call at least once a week to other units even if it is not really important to build a culture so that talking with each other becomes easy. They should not think twice IS IT OK to call Mr. XYZ? They should just call because it solves problems much easily*". Furthermore, the interviewee Z also claimed that keep on asking just to know the status of work as "*Don't wait for big-bang*". Therefore, to increase socialization in GSE teams always share and transfer knowledge, discuss issues and ideas, make frequent telephonic calls, emails and chatting. Moreover, by increasing informal ways of sharing knowledge will increase socialization which will in turn help in building

team and thereby reducing requirements misinterpretations caused due to co-ordination breakdown and geographic dispersion in GSE.

5.6.　　　Product Architecture

According to Carmel [21], product architecture should be designed in such a manner so that dispersed units can be less dependent on each other work. Besides, as in GSE teams are scattered therefore it is always hard to communicate, collaborate and coordinate due to distance and difference in time zones.

From industrial interviews the authors' found that both Company A and Company B have the good approach of modularization in which they ensure to have little dependency on each other i.e. component ownership. Furthermore, they also have incremental approach for product development. Besides, the interviewee Z at Company claimed that "*Don't wait for big-bang*" i.e. always frequently communicate, increase feedbacks and increments because it is an easy way to solve problems. In addition, Smite [87] study shows that complex task division makes the process of coordination and collaboration more complex.

As requirements understanding is not confined only to RE phase but is an ongoing process throughout SDLC therefore modularization helps in requirements understanding and especially in GSE where teams are dispersed geographically. Moreover, as in GSE modularization helps in reducing dependencies of units on each other therefore it helps in overcoming issues of geographic dispersion, coordination breakdown, loss of teamness and difference in time zones faced in requirements understanding in GSE.

5.7.　　　Static Validation of Results

For static validation of results a brief presentation was given to the practitioners in industries which were interviewed earlier. In presentation the authors presented the results of literature review and industrial input. Besides, after presenting the results the authors asked several questions from interviewees regarding the suitability and reliability of the results like "*What are the main driving forces to overcome GSE challenges?*", "*How much suitable our results/solutions suitable for Global Managers to cope with GSE challenges?*", "*What are the main factors which causes misunderstanding of requirements in GSE?*" and so on. The interviewees agreed with our results and focused on the importance of sharing knowledge continuously.

The interviewees commented that the three most important centripetal forces after having a good support of Telecom Infrastructure are Collaborating Technology, Team Building and Managerial Techniques can leverage the rest of the centripetal forces suggested by Carmel [21]. Moreover, the reference model which authors have presented can be used as a guide by Global Mangers involved in GSE.

5.8.　　　Validity Threats

Validity threats are essential part of any research study, which improves the accuracy of a research study by identifying all those key factors which can lead to affect the results. According to Wohlin [79], there are four different types of validity threats namely external validity, construct validity, internal validity and conclusion validity which are discussed in the light of this study.

5.8.1. External Validity

External validity is used to determine whether the results of conducted study can be applied in other domains as well or not [79].

According to Wohlin [79], the interaction of selection and treatment is among one of the threats to external validity. This type of threat occurs when wrong subjects are selected from the population which can affect the results of a research study because the results of such a research study cannot be generalized and applied to the whole population. In the context of this study all of three interviewees were selected from the domain of the intended research area i.e. RE activities.

Furthermore, both of the companies i.e. Company A and Company B were involved in GSE and were working in the same domain of Telecommunication. One of the possible threats to the results of this study is the domain of the companies, due to which it cannot be generalized to the companies involved in software development other than telecommunication. However, the focus of this study is more related towards human activities of RE i.e. is not related more towards technicality issues, therefore, authors believe that the results can also be helpful for software companies involved in GSE other than telecommunication.

5.8.2. Construct Validity
Construct validity is the degree of relationship between theory and observation [93]. Further, construct validity is an assessment of how one can translate his/her ideas or theories into actual programs or measurements.

According to Wohlin [79], evaluation apprehension is a main social threat to construct validity. It means that some people try to show themselves smart and feels well, while there are some people who are afraid of being evaluated. As the authors have conducted interviews in two companies therefore they were ensured prior to the conduction of interviews that their names and company names will be kept confidential.

According to Wohlin [79], another important threat to construct validity is mono-operation bias which means to select only one independent variable, cause, program or treatment in the whole research study. In order to eliminate this threat authors have conducted three industrial interviews in two different software companies. Two interviewees were selected from Company A and were working as Technical Product Manager (TPM's) and one was selected from Company B, who was working as a Supplier Manager.

5.8.3. Internal Validity
Internal validity is the relationship of causes and effects or causal relationship. Thus, internal validity identifies the facts due to which it enables researchers to draw conclusion from causes and effects. Further, it also pinpoints all those factors which can affect independent variables with out researchers' knowledge [79].

It is quite obvious that people do not feel relax, secure and comfortable when their voice is recorded. As all of interviews were recorded so therefore, to eliminate this threat to conclusion validity the interviewees were ensured prior to interview that the recordings will be confined to the authors only and will be destroyed after using it for the research study.

Another potential threat to internal validity is the selection of subjects from population. This threat is eliminated by selecting interviewees working in the same domain of the study i.e. RE. However, one of the interviewee was not directly related to RE. But authors believe that he had sound knowledge, educational background and experience of RE activities performed throughout SDLC. Besides, he was also indirectly involved in RE activities carried out in his company due to his position as a Supplier Manager.

5.8.4. Conclusion Validity

The purpose of conclusion validity is to testify that results drawn from a study are reliable and can provide correct conclusion. Further, threats to conclusion validity of the research study are concerned with issues and factors which can affect the reliability of the results i.e. by affecting the potential to draw conclusion [79].

The first possible threat to the conclusion validity is the designing of questionnaire which was used for collecting of data from industries. But this potential threat was eliminated by validating the questionnaire from two researchers and some senior students who had already finished their research work.

Another possible threat to conclusion validity which can affect the reliability of the results is the heterogeneity of subjects [79]. Heterogeneity of subjects can be defined as when selected subjects have different educational background and have different experiences then it is known as heterogeneity. Homogeneity is opposite of heterogeneity where subjects have same educational and experience background. In case of this research study, as discussed in (see Section 4.1.2) that interviewee X and Y were from the same Company A and also had almost same experience i.e. thirteen years of interviewee X and eleven years of interviewee Y. Besides, the interviewee Z at Company B (see Section 4.2.2) had three years industrial experience and had sound academic experience as well. Therefore the results of the study cannot be affected by these subjects because the subjects were more towards homogeneity rather than towards heterogeneity.

5.9.   Summary of the Chapter

The aim of this chapter was to answer the third research i.e. "How KM practices helps to reduce requirements understanding problems in GSE?" This chapter contributed to answer the research question in number of ways. Firstly, the authors have identified and discussed KM practices from RQ1 which can supplement Carmel solutions. Secondly, a discussion has been made on how all those identified KM practices helps in requirements understanding in GSE environment. In addition, the solutions and practices identified from RQ2 which are used both in industries and literature were also mentioned and discussed. Moreover, static validation of results and threats to validity of this research study were also discussed in detail.

6   EPILOGUE

This chapter comprises of research questions revisited, conclusion of the thesis, some recommendations and future work.

6.1.   Research Questions Revisited

RQ1. *What is the current state of practice of KM?*

In the context of this thesis the authors only performed a literature review of KM. This was done to build a knowledge base for the intended readers and to know the importance of KM. Besides, different KM practices which are discussed in (See Chapter 3) were identified to be useful for overcoming requirements understanding issues faced in GSE (See Sections 5.1-5.6).

RQ2. *What are the challenges of requirements understanding in GSE?*

In this thesis the authors answered this research question in two phases i.e. literature review and industrial interviews. First of all a thorough literature study was performed (See Section 2.3.2) which identified several GSE challenges and their impact on requirements understanding. Besides, as the authors study was only based on Carmel [21] work so therefore the authors only considered GSE challenges identified by him (See Section 2.4.1). Secondly, industrial interviews were conducted which also identified problems faced in requirements understanding due to GSE. Furthermore, an interesting thing which the authors found from industrial interviews was time zone difference as a GSE challenge which was not included in Carmel [21] study so therefore the authors added it to the list of GSE challenges.

RQ3. *How KM practices helps to reduce requirements understanding problems in GSE?*

In this thesis the research question was addressed both from literature review i.e. knowledge gained from RQ1 and RQ2 and industrial interviews. Besides, the discussion of KM practices helps in requirements understanding is made in (See Sections 5.1-5.6) and the compact form is given in the form of a table (See Appendix A).

6.2.   Conclusion and Recommendations

Based on the analysis of literature review and industrial interviews the authors have concluded that requirements understanding issues in GSE occurs due to lack of knowledge sharing and communication, lack of interaction, culture diversity, mutual discussions, lack of face-to-face meetings, co-ordination and communication breakdown due to time zone difference and loss of teamness and so on. Besides, the authors consider that time zone is a challenge in requirements understanding and industries have several issues when discussing and understanding requirements issues due to larger differences in times zones. Therefore, following recommendations can be made:

- Always share knowledge and communicate even if it is not necessary because it helps in creating trust, mutual understanding, increases collaboration and co-ordination which in turn reduce requirements understanding issues.
- For requirements understanding, build communities because it helps in problem solving, knowing each other, better competence identification and utilization.
- Motivate team members to share and codify knowledge of requirements because it helps in reducing requirements understanding issues.
- Always arrange kick-off meetings and face-to-face meetings because it helps in knowing each other, create trust and motivation among team members and requirements issues are better resolved in this fashion.

- Provide a good telecom infrastructure that can not only support efficient and reliable communication but can also support KM tools in order to enable team members to share and access knowledge easily from anywhere in the world.
- For requirements to be more clear, put them in some context, elaborate and discuss it with help of visualization i.e. diagrams and pictures.
- The use of standardization throughout organization can also helps in reducing requirements understanding issues.
- Invest in hiring culture liaisons/brokers can help in reducing issues of requirements understanding by providing knowledge of culture, people and product.
- It will be good for organization to hire some technical experts who can help in problem solving and also help in referring to some other competent person.

Moreover, in GSE requirements understanding issues are faced not due to lack of competence but due to lack of sharing and communicating knowledge. Therefore, always motivate team members to share knowledge formally and informally to reduce requirements understanding issues.

6.3.   Future work

- As the authors have only identified the useful KM practices for reducing requirements understanding issues in GSE so therefore there is a need to design a KM framework.

- It can be a useful contribution to research for evaluating the effectiveness of KM practices for reducing each and every GSE challenge i.e. culture difference, loss of teamness, loss of communication richness and so on impact on requirements understanding.

- As the authors performed only qualitatively research. Therefore, in future a quantitative study is needed to see the effectiveness of KM practices in reducing requirements understanding challenges in GSE.

- As authors have conducted the interviews in only two industries working in same domain i.e. Telecom, so therefore it would be a future work to see the results if the interviews are conducted in more than two industries working in different domains.

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APPENDIX A: REFERENCE MODEL

	Collaborating Technology	Telecom Infrastructure	Managerial Techniques	Development Methodology	Team Building	Product Architecture
Culture Differences	DM[Int,9,58,64,81], CM[Int,9,58,64], Intranets[81,82], Video/Audio Conferencing[Int,26,64], Email[Int,64,82], Chatting[Int,64,71], Forums[Int,64,71,82]	Telephone[Int,7,83], Internet[Int,58]	Job Rotation[Int,9], Motivation[7], Trust[7,85]	Electronic Process Guides[86] i.e. Standards[87] & Terminologies[27,88]	Visiting[Int,85]/Meeting Face to Face[Int,7,64,89], Training(for awareness, language and culture)[Int,90], Trust[Int,7,85], Liaisons[Int,32,91] /Brokers[Int,7]	X
Geographic Dispersion	DM[Int,9,58,64,81], CM[Int,9,58,64], Intranets[81,82], Video/Audio Conferencing[Int,26,64], Email[Int,64,82], Chatting[Int,64,71], Forums[Int,64,71,82]	Telephone[Int,7,83], Internet[Int,58]	Motivation[Int,7], Trust[Int,7,85]	Electronic Process Guides[86] i.e. Standards[87] & Terminologies[27,88]	Visiting[85], Frequent Informal Communication (Telephone, email, chat)[Int,87], Training[90], Trust[7,85]	Modularization[Int,88]
Loss of Communication Richness	Video/Audio Conferencing[Int,26,64], Visualization(visual representation of requirements[Int,64,83], Informal Communication (Email, Phone, Chat)[Int,87], Forums[Int,64,71,82]	Telephone[Int,7,83], Internet[Int,58]	X	Electronic Process Guides[86] i.e. Standards[87] & Terminologies[27,88]	Visiting[Int,85]/Meeting Face to Face[Int,7,64,89], Trust[Int,7,85], Motivation[Int,7]	X
Co-ordination Breakdown	CM[Int,9,58,64], DM[Int,9,58,64,81], Telephone Calls[Int,64], Chatting[Int,64,71], Email[Int,64,82], Forums[Int,64,71,82] Intranets[Int,81,82]	Telephone[Int,7,83], Internet[Int,58]	Motivation[7], Trust[7,85]	Electronic Process Guides[86] i.e. Standards[87] & Terminologies[27,88]	Frequent Informal Communication (Email, Telephone, Chat)[Int,87], Trust[Int,7,85]	Modularization[88]
Loss of Teamness	CM[Int,9,58,64], DM[9,58,64,81], Telephone Calls[Int,64], Chatting[Int,64,71], Email[Int,64,82], Forums[64,71,82]	Telephone[Int,7,83], Internet[Int,58]	Rewards[Int,7,9], Motivation[Int,7], Trust[Int,7,85]	Electronic Process Guides[86] i.e. Standards[87] & Terminologies[27,88]	Kickoff Meetings(Introduction of Team Members)[Int,10,89], Visiting[Int,85], Trust[Int,7,85], Motivation[Int,7]	Modularization[Int,88]
Time Zone Difference	Email[Int,64,82], Communities[Int,9,71]	Internet[Int,58]	X	Electronic Process Guides[86] i.e. Standards[87] & Terminologies[27,88]	X	Modularization[88]

Int→ Stands for Interviews

APPENDIX B: QUESTIONNAIRE FOR INDUSTRIAL INTERVIEWS

Introduction Part

a) **What is your name?**

b) **What is the name of your organization?**

c) **What is your current position in your organization?**

d) **What is your education background?**

e) **What kind of work experience do you have?**

f) **Are you involved in Requirements Engineering (RE) activities within/outside your organization?**

Domain Specific Questions

1. **Please describe the structure and division of work in your project across different sites with focus on requirements understanding?**

2. **Please describe in detail about the product and its history?**

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_____

_____

_____

3. **How requirements are handled across different units?**

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_____

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4. **Describe in detail about the cultural differences you have experienced and how they have affected your project? How do you overcome those culture problems?**

_____

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5. **How are requirements interpretations achieved and aligned across different units?**

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6. **How do you manage communication? Which tools and techniques are used to communicate requirements?**

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7. **How do you co-ordinate with each other for a specific problem to be solved? Which kind of tools and techniques are used for co-ordination?**

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8. **Describe how informal communication takes place. How do you utilize it?**

_____

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_____

9. **Do you have any face to face meetings? Any video conferencing? Tell me how does it work?**

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_____

10. **How does the collaboration tool lack the richness level of collaboration between remote sites for requirements understanding and why?**

_____
_____
_____
_____

11. **Describe how geographical dispersion has affected your project? What kind of tools, mechanisms and processes do you use to overcome the geographical dispersion problem?**

_____
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_____
_____

12. **How do you manage team work across dispersed units?**

_____
_____
_____
_____

13. **How do you do standardization (uniformity) of e.g. development methods, different standards, templates and patterns etc across different units?**

_____
_____
_____
_____

14. **How do you extract and manage the tacit knowledge of culture, people interests, product domain knowledge, customs knowledge etc present with requirements? Do you use some training, liaisons, workshops, taking assumptions etc?**

_____
_____
_____
_____

15. How do you manage job rotations, hiring professional personnel and division of work into units and its impacts on requirements understanding? What kind of problems are faced in it and why?

_____
_____
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_____

16. What are your experiences about the Knowledge Management term "We can know more than we can tell" and its impacts on requirements understanding? Why?

_____
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_____