Learning, knowledge creation and performance in Six Sigma projects

By

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DECLARATION OF AUTHENTICITY AND AUTHOR RIGHTS

This thesis is the result of the author’s original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed:

Date: 20.05.2015

Dedicated to:

My parents A. Velayudham Pillai and A. Neela for their support

and

My wife A.P. Selvi whose love and inspiration made this possible

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ABSTRACT

Coined by Motorola in 1986 as a metric for measuring defects and improving quality, Six Sigma has evolved into a robust business improvement initiative. The success of Six Sigma deployment depends on a series of process/quality improvement projects undertaken by organizations. As learning and knowledge creation is vital to problem-solving environments, the primary objective of this thesis is to investigate the role of learning and knowledge creation on project performance and factors that impact them. The research addresses ‘‘Six Sigma-learning-performance’’ relationships through three related studies:

(1) Develop a multilevel framework of Six Sigma linking organizational actions (macro), project execution (micro), and business performance (macro)
(2) Identify the distinct learning behaviours exhibited by project teams and empirically investigate the impact of managerial factors (organizational and project level) on learning behaviours and in turn on project performance
(3) Empirically examine how the motivational aspect of team and technical aspects of project execution interact to impact project performance through knowledge created (Goal theory and Sociotechnical systems theory perspective)

The research adopts an *explanatory sequential mixed- methods design*, a survey followed by a multiple case study research (Quantitative Qualitative). In addition, the research observes the interaction between quantitative and qualitative research strands to achieve interpretive rigor. The quantitative data come from 324 members (project leaders and members) from 102 Six Sigma project teams and the qualitative data from five case projects from two European manufacturing organizations.

Building on the existing literature which notes that Six Sigma supports learning and knowledge creation in teams, this research *extends and helps refine* our understanding of Six Sigma by explaining the mechanisms underlying the phenomenon and their antecedents and performance consequences.

The thesis will be of interest to managers who are engaged in Six Sigma deployment and project leaders who lead process improvement teams. Researchers working in the field of Six Sigma will also benefit from this research.

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CHAPTER 1

INTRODUCTION

Coined by Motorola in 1986 as a metric for measuring defects and improving quality, Six Sigma has evolved into a robust business improvement strategy (Antony, 2004a; Harry and Schroeder, 2000; Schroeder et al., 2008). Started in the manufacturing sector in the early years, Sigma has now been increasingly adopted and accepted in service organizations such as health care institutions, the finance sector, airlines, utility services and call centers. Six Sigma impacts business performance by improving various business dimensions of organizations, such as business processes, internal resource capability, customer satisfaction, and finally profitability (Shafers and Moeller, 2012; Swink and Jacobs, 2012; Zu et al., 2008). Deployment failures are also reported, but attributed primarily to inappropriate deployment strategies (Chakravorty, 2009b).

Six Sigma has enjoyed considerable popularity and acceptance for about a quarter of a century, which is unique in the operations management field considering its origin from practice. Since it evolved from the practice, scholars have called for scholarly inquiry to develop an in-depth and scientific understanding of Six Sigma (Schroeder et al., 2008; Antony, 2008). Only a small number of studies have been conducted to help explain the phenomenon and its theoretical underpinning (Schroeder et al., 2008; Braunscheidel et al., 2011). The academic world has a crucial role to play in bridging the gap between the theory and practice of Six Sigma (Antony, 2008).

1.1 Multilevel framework of Six Sigma

Practitioners have acknowledged that Six Sigma is a multi-level phenomenon involving both organizational and project level members (Pande et al., 2000; Snee and Hoerl, 2003; Pyzdek, 2003; Harry and Schroeder, 2000). Research evidences suggest that Six Sigma involves organizational actions and project execution (Antony and Banuelas, 2002; McAdam and Lafferty, 2004; Nair et al., 2011; Choo et al., 2007; Linderman et al., 2010; Zu et al., 2008; Schroeder et al., 2008; Anand et al., 2009; Kumar et al., 2008; Nonthaleerak and Hendry, 2008). Although Six Sigma involves organizational actions (macro), project execution and outcome (micro) leading to business performance (macro), the ‘‘organizational actions-project execution-business performance’’ relationship is under-theorized in the extant literature. A multilevel framework of Six Sigma, connecting organization, project and performance can help uncover the gestalt of Six Sigma and the theory underpinning the phenomenon. It can provide more insights into the steps individual actors take to yield organizational benefits. Multilevel research bridges the micro/macro divide, integrating the micro domain’s focus on individuals and groups with the macro domain’s focus on organizations, the environment and strategy (Klein, Dansereau and Hall 1994; Klein, Tosi and Cannella 1999: Harrison and Klein 2007). Multilevel studies provide insights into the knowledge of the impact of the organizational context on individuals’ actions and perceptions and the influence of individuals’ actions and perceptions of the organizational context (Klein et al., 1999). This research aims to develop a multilevel framework of Six Sigma through a systematic literature review.

Noted quality authority Joseph M Juran said that ‘‘All quality improvements take place project by project and in no other way’’(Juran, 1989, pp. 35). Six Sigma primarily takes a strong project-based perspective of quality improvement. Deployment involves carrying out a series of projects to improve the processes that enhance the quality of products or services coming out of these processes. Organizations deploy quality improvement programs such as Six Sigma, with the hope that these programs increase performance and outweigh the investment made toward deployment. The primary challenge faced by the organizations in deploying Six Sigma is to ensure that the series of improvement projects executed in their organizations succeed and bring out process improvement and quality enhancement leading to improved financial performance. Hence, project performance becomes an important factor in a successful deployment of Six Sigma. Studies that investigate the factors that enhance project performance, therefore, are critical to predictions and explanation and for providing managerial relevant advice. Only a few studies examine the performance consequences of Six Sigma at the project level (Linderman et al., 2006; Choo et al., 2007b; Anand et al., 2010). There is a timely need for more extensive research at the project level to explain the phenomenon at micro level. This study aims to join this stream of research and aims to contribute to knowledge by developing a deeper understanding into Six Sigma phenomenon via empirical investigation into the activities within project execution and identifies factors that impact project performance.

1.2 Learning in Six Sigma teams

The recent research in Six Sigma project teams provides evidence that learning and knowledge creation mediate the performance consequences (Choo et al., 2007; Anand et al., 2010). However, the literature fails to fully explain the various mechanisms or behaviours by which a team learns and factors that affect these learning behaviours. In this research, the broader research question, ***'How does learning take place in a Six Sigma project team?'*** challenges practicing managers to channelize their efforts and to provide necessary input so that improvement projects are executed successfully, and the anticipated project performance is achieved. Research on learning and knowledge management is preoccupied with macro-level studies (firm or organizational level) and pays little attention to micro-level constructs, such as individuals and group/teams. Scholars argue that the actual mechanisms producing observed correlations can be identified and revealed only by micro-level studies (Coleman, 1990; Foss, Husted and Michailova, 2010; Edmondson, 2002). This research contributes to this stream of research by conducting an empirical investigation on learning at the project level (micro-level). This research focuses not only on the mechanisms of learning in project teams, but also on the influencing variables and their impacts on project performance.

Knowledge management literature is of the view that organizational learning takes place through individuals (Simon, 1991), is moved up through groups and then to the overall organization. Organizational learning is viewed in two different ways in the literature, as an outcome and as a process. Levitt and March (1988) conceptualized organizational learning as the outcome of the process of organization. The second perspective of learning is a process of detecting and correcting errors (Argyris and Schön, 1978). The researcher joins the latter tradition in treating learning as a process leading to improved performance. Through a set of behaviours, team learning is enacted in teams (Edmondson, 1999). Learning process involves various behaviours through which such outcomes as adaptation to change, greater understanding, knowledge creation and improved performance in teams transpire. In this research, team learning is conceptualized as a team level process involving reflection and action, characterized by asking questions, seeking feedback, experimenting, reflecting on the results, and discussing errors or unexpected outcomes of actions (Edmondson (1999).

1.3 Research Context

The researcher has been involved in a number of process improvement activities in his career, both as a consultant and as an operational and quality improvement professional in various organizations spanning more than two decades. For the last eight years, the researcher has been working in the field of Six Sigma implementation in many organizations. The researcher has also been involved in the deployment of Six Sigma in many of the strategic suppliers of the organization around the world. As a member of the Six Sigma educational certification board in his present organization, the researcher has been responsible for assessing projects and capabilities of the project leaders for certification. As a part of his responsibility, the researcher has also been involved in training, coaching and mentoring many Six Sigma project teams and has observed how members learn and solve problems.

Based on the experience gained during the course of his profession, the researcher came to a firm conviction, not only about the approach followed in Six Sigma which is different from other Quality management (QM) initiatives, such as Total Quality Management (TQM), but also the way people, especially the members of the project learning behaviors that are distinctly different from that found in other QM initiatives. Learning takes place systematically and sequentially and is guided by the structured method which a project team follows during the project execution. The team learns about the process it is trying to improve by step by step approach. During the initial phase of the project, the team obtains an introductory overview, and as the project progresses, team attains knowledge to a level that helps them improve the process. The teams, learn and solve problems while working on improvement projects. An important aspect the researcher found, first, is that Six Sigma project team exhibits team applies scientific principles and various tools and techniques to reach the optimum solution based on the new-found knowledge. Through their knowledge gathering behaviour, project leaders stimulate and encourage learning in teams and help synthesize individual knowledge into group level knowledge to solve problems. Leaders facilitate the members toward acquiring and generating new knowledge. In this process, members learn from each other, develop their skills and knowledge, and contribute to organizational knowledge.

Second, the success of a Six Sigma project depends not only on how systematically and sequentially a team learns and creates knowledge to solve problems, but also on how various dimensions of project execution facilitate the learning process. These two striking observations intrigued the researcher to pursue doctoral research in this unexplored area. The researcher is highly motivated to explore the learning behaviours of the Six Sigma project teams to assess how these behaviours impact project performance and to identify the factors that influence these behaviours and in turn project performance. The research findings can offer input and advice to practicing managers for their considered decision-making process for improving organizational effectiveness.

The researcher used a particular theoretical approach to look at learning in Six Sigma projects, which is a process view because of his engineering background. As a starting point, he assumes that the process view of ‘learning’ in the Six Sigma project would provide useful insights into clarifying what goes on within the team during project execution. The process view posits that input factors affect the output performance through certain kinds of interaction processes with a causal linkage between various factors (Figure 1.1). In the context of learning in Six Sigma, the input factors are learning enablers (Context and Antecedents) that affect learning behaviours (Actions) and learning outcome (Result: project performance). Feedback and performance information are used continually to adjust the inputs, the process and the characteristics of the outputs.

While reflecting on learning behaviours in project teams, the researcher also considered other influencing fields of research, such as team learning, work motivation, and organization development, which have close relationships with team learning. This reflection led to the research topic ‘Learning in Six Sigma’ being positioned as a research subject along with these research fields as shown in Figure 1.2.

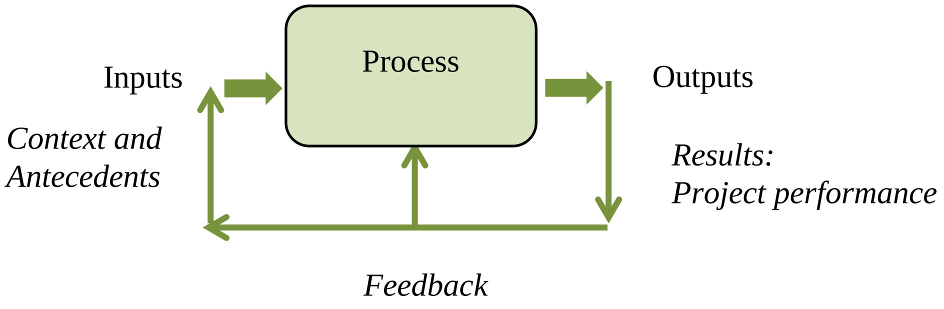


Figure 1.1 Process model

This multi-disciplinary research will advance our understanding of Six Sigma phenomenon. The findings would provide guidance to practicing managers for informed decision-making and would help them for successful implementation of Six Sigma projects and hence successful deployment of Six Sigma.

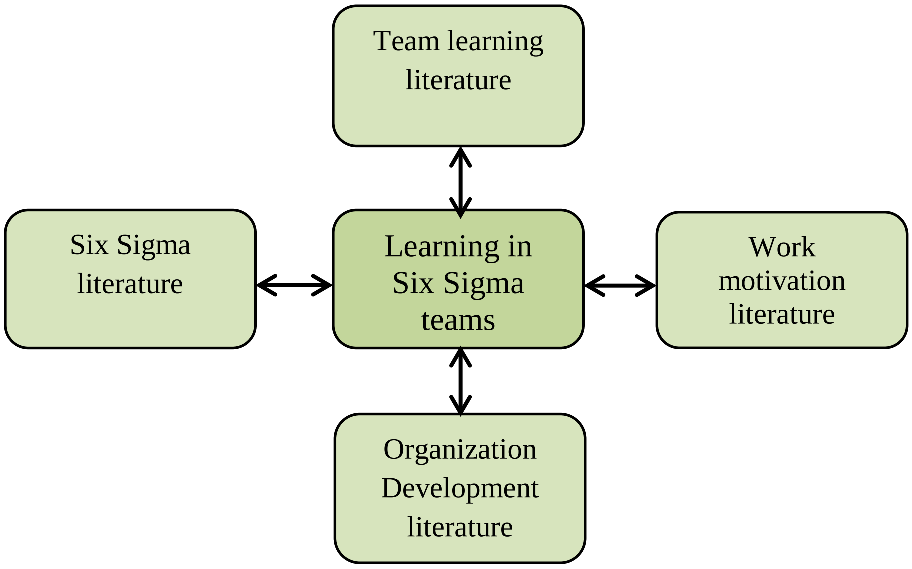


Figure 1.2 Positioning of Learning in Six Sigma teams as a subject

1.4 What does this Research do (Research objectives)?

The *first objective* of this research is to systematically review and synthesize the state of academic research on Six Sigma and business performance into a comprehensive multilevel framework linking leadership, Six Sigma dimensions and performance outcome (Study 1). Through the systematic literature review, the researcher brings together a number of different perspectives of Six Sigma to understand how Six Sigma influences business performance through various dimensions.

The *second objective* of this research is to look at learning behaviours of Six Sigma project teams, their antecedents, and the relationships to project performance. The research aims to bring together current thinking in the field and carry out an empirical investigation to clarify and advance our understanding of the topic.

Operations management scholars have found that process improvement contributes to the competitive positions of organizations (Anand et al., 2009; Shah and Ward, 2003), and recognize the importance of learning and knowledge management in process improvement (Choo et al., 2007; Linderman et al., 2004). In spite of the importance of the knowledge management within the firm (Sutton and Hargadon, 1996), few studies investigates the relationship between knowledge management and quality management, in general, and process management in particular (Choo et al., 2007; Linderman et al., 2010; Zhang et al., 2008). Only a few studies focus on influencing variables and their effects on learning and knowledge (and in turn on project performance in Six Sigma projects (Anand et al., 2011; Choo et al., 2007; Gutierrez et al., 2011; Linderman et al., 2010). Scholars have also noted that technical and social components of quality management lead to learning and knowledge creation (Hackman and Wagemen, 1995; Wruck and Jensen, 1994), and organizational factors such as managerial actions and contextual factors influence learning in teams (Cohen and Levinthal, 1990; Van den Bosch et al., 1999; Edmondson, 1999). Although prior research has shown that learning and knowledge creation enhance performance (Choo et al., 2007; Anand et al., 2010), we do not know the mechanisms, or more specifically the different types of learning behaviour or learning activities that are exhibited in project teams and their effects on project performance. The current research fills that research gap by investigating learning behaviours in Six Sigma process improvement teams. The research is a point of departure for fresh lines of inquiry using quantitative study, followed by a confirmatory qualitative study on various learning behaviours in project teams, critical antecedents, and their performance consequences.

1.5 Research questions

The broad research question: *How does learning take place in a Six Sigma project team?* In order to answer this research question, the researcher developed the following *four specific research questions* from a critical review of the relevant literature (Chapter 3).

Research Question 1*: What are the different learning behaviours of Six Sigma project teams?* This research question aims to clarify learning activities within the project team that facilitate project success (**Actions: learning behaviours**).

Research Question 2*: How do the learning behaviours of teams impact project performance?* The answer to this question will explain the relationships between learning behaviours and project outcome (**Causal linkage: Actions → Outcome**).

Research question 3: *How do managerial factors (organizational and project level factors) impact learning behaviours and in turn project performance?* The answer to this question will explain the relationships between learning behaviours, their antecedents and project outcome (**Causal linkage: Antecedents → Actions → Performance)**.

Six Sigma projects are set with challenging goals, sometimes as high as tenfold (Pande et al., 2000; Linderman et al., 2003). According to Goal Theory, this challenging goal lead to more effort, persistence and direction by team members than vague goals resulting in improved performance (Locke and Latham, 1990; Linderman et al., 2003, 2006). In the context of Six Sigma, Linderman et al (2003) have noted,‘‘improvement goals motivate organizational members to engage in intentional learning activities that create knowledge and make improvements’’(Linderman et al., 2003, pp. 193-194). Six Sigma project teams use a highly structured method while executing projects. This structured approach employed by the project team (DMAIC or its variants) is similar to the PDCA cycle (Shewhart, 1931), and it promotes rational decision-making (Daft, 2000). The approach adopted creates knowledge through problem-solving that facilitates rational decision-making (Cyert & March, 1963). Choo et al. (2007b) argue that the structured ‘‘method represents a cognition-influencing mechanism that leads to learning behaviours and knowledge created in quality improvement teams’’(Choo et al., 2007b, p. 438). The team uses a variety of tools and techniques to capture the explicit and tacit knowledge of team members for achieving specific project goals (Anand et al., 2010). Linderman et al. (2006) find evidence to show that Method and goal interact to impact project performance. It is quite likely that the social aspects of goal setting (motivation) and technical aspects of project execution (DMAIC) interact to affect learning and in turn project performance. The relative importance of the structured method and challenging goals for knowledge has not been examined directly in the prior literature, although Linderman et al. (2006) find evidence to show that method and goal interact to impact performance in Six Sigma projects.

Thus, our last research question:

Research question 4: *How do social aspects of the project team (goal) and technical aspects of project execution (method) interact to impact project performance through knowledge creation?*

This research question will investigate the interaction between social and technical factors and its effects on learning and in turn on the performance. The study uses the **goal setting theory** of work motivation research discipline and the **Sociotechnical System (STS)** theory of the organizational development research to explicate the interaction effect between project goal and structured method **(Causal linkage: Antecedents/Context → Action → Performance).**

The answers to the above four research questions will provide a process based explanation (antecedents-process-output) of learning and performance in Six Sigma teams. And they will help explain and predict the performance consequence of Six Sigma project.

The research objectives are set to be accomplished by the following research and field work.

- *Develop a literature based conceptualization of learning behaviours*
    - Building on Six Sigma and team learning literatures, identify the distinct learning behaviours exhibited in Six Sigma projects

- *Develop and test hypotheses to answer the four research questions (RQ1-RQ4) and explain the relationships between learning behaviours, managerial factors, and project performance*

- Conduct a sequential mixed methods research (Quantitative→Qualitative)
- Collect quantitative data through a survey research and establish hypothesized relationships between critical managerial factors (organizational and project level), learning behaviours, and project performance
- Conduct a multiple case study research (case projects from the survey participants) and explain and corroborate the findings of the quantitative research

Overall, the aim of the research is to provide insights into the Six Sigma phenomenon by investigating learning behaviours, factors that impact these behaviours and the association between these factors and performance. In conclusion, this research adds to the discussions of the performance consequences of Six Sigma, but from a project-level perspective. The findings will help extend and refine the existing stock of knowledge on Six Sigma and shed light on the factors affecting project performance. The research will provide a foundation for future work into how successfully Six Sigma adoption can be achieved.

The subsequent chapters will discuss the development of a multilevel framework of Six Sigma, a focused set of four research questions, a conceptual research framework, eight testable hypotheses and the research conducted to test them, and answer the research questions.

1.6 Scope of research

Traditionally, Six Sigma was started in manufacturing organizations and deployment has been found to be mature in manufacturing organizations (Antony, 2004b; Schroeder et al., 2008). It has now been increasingly adopted and accepted in service organizations and recently in other sectors such as educational sectors (Antony et al., 2012). It is also reported that there is not much difference in terms of implementation processes between manufacturing and service industries (Antony et al., 2007a; Chakrabarty and Taan, 2007; Timans et al., 2012; Antony et al., 2008; Kumar, 2007; Cho et al., 2011). In order to limit the scope of the research, based on the researcher's background and personal interest, the ***research focuses only on***

manufacturing organizations. The findings, however, can be applied to other business sectors.

Second, conducting a research globally by taking samples across the globe would involve a myriad of factors, including country and cultural factors which may invariably make the research too complex to be planned and executed within the time frame of the PhD efforts. The present research, therefore, is limited to ***European manufacturing organizations*** and more particularly to Denmark and Sweden, where the researcher has access to data. Future global research could be an extension of the present research.

Third, learning in a Six Sigma project team is a very complex phenomenon involving a multitude of managerial factors (organizational and project level) that may affect learning in project teams. In order to reduce the complexity of data collection and analysis (considering the research period for the Ph.D work and resources available), ***the present research is restricted to only four critical factors as informed by extant literature.*** Focusing on a large number of organizational and project level factors that may potentially influence learning in project team could be a topic for a future research.

1.7 Research Approach

Figure 1.3 displays the research approach used in this study. Study 1 (chapter 2), through a systematic literature review of Six Sigma, develops a multilevel framework of Six Sigma linking managerial actions, project execution, and performance. The review brings out patterns that show apparently there are differences compared to previous quality management programs in the way Six Sigma is structured in organizations and in the ways project teams operate in solving process and quality related problems. The review highlights various factors of project execution that facilitate learning and knowledge creation and in turn on the performance.

Through a focused review of Six Sigma and team learning literature (chapter 3), the researcher develops a conceptual framework for the research and eight testable hypotheses on learning in Six Sigma. Drawing on literature, study 2 proposes and explains the process improvement success through two distinct learning behaviours (*knowing-what* and *knowing-how*). The study validates the scale items for the two

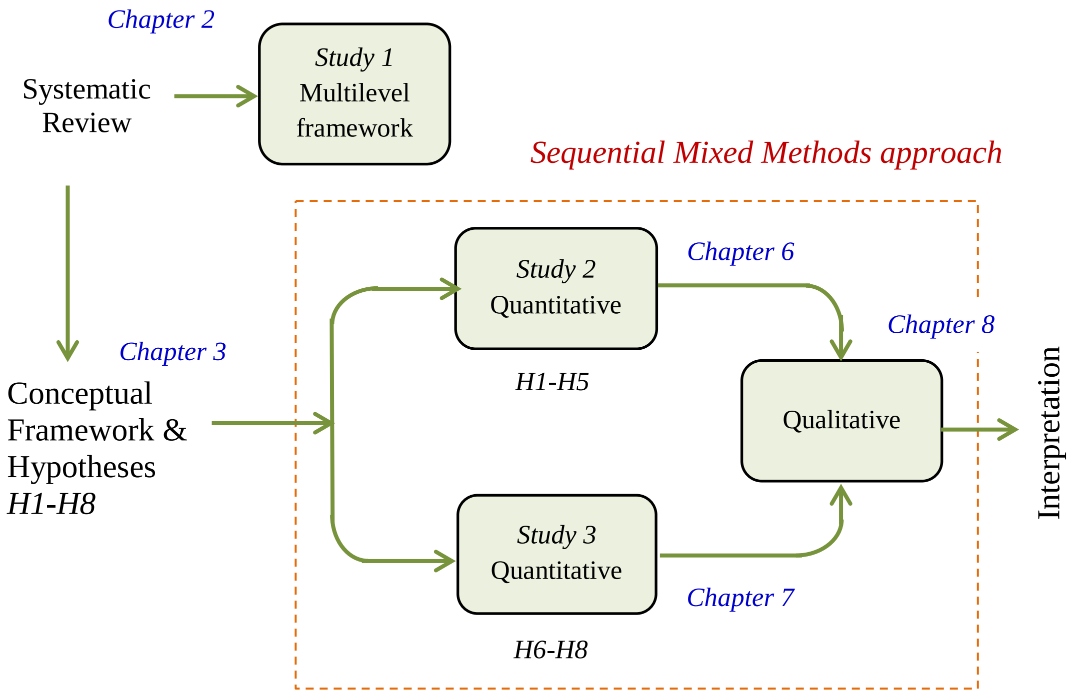


Figure 1.3 Research approach

learning behaviours identified, and investigates the relationship between learning behaviours and performance. Further, this study examines the impact of the following four factors, which have potential impacts on the two learning behaviours and in turn on project performance.

- Project resources provided by management (organizational level factor),
- Adherence to structured method in projects (project level technical factor)
- The project leader's knowledge gathering behaviours (project level factor)
- Team psychological safety (project level social factor, which is found to affect learning in teams in team learning literature)

Study 3 builds on the Goal Theory perspective of Six Sigma to investigate the influence of the project goal and structured method on performance through knowledge created in teams. Goal Theory and Sociotechnical System theory (STS) are used to explain the interaction of the motivational aspect of goal and technical aspects of the structured method in affecting project performance. Data for study 2 and 3 come from 102 project teams comprising 324 members (102 project leaders and 222 team members) from two organizations (52 and 50 projects respectively).

The qualitative research (case study) is used to explain and support the findings of Study 2 and 3 and to identify any new factors or themes that emerge. The case study uses 5 case projects selected from the participating projects of the survey, and the selection is based on certain selection criteria to help elaborate and explain any unexpected results of the survey research. Further quantitative data analyses are also carried out to confirm any special and unexpected findings of the case research. Thus, this research design observes the interactions between qualitative and quantitative research strands and help enhance interpretive rigour.

A journal paper based on the Study 2 was published in *International Journal of Production Economics* in 2013, and a paper based on the Study 1 (multilevel framework of Six Sigma) was published in the *Quality Management Journal* in 2014.

1.8 Organization of the thesis

The structure of the thesis is as follows. Each chapter of the thesis starts with a chapter goal that briefly explains what is expected of the chapter and how this is relevant to the research topic. At the end of each chapter, a summary is provided to inform the reader about the extent to which the objectives are met in that chapter, including some critical messages emerging if any. The thesis is structured in 9 chapters, which are introduced below.

Chapter 1 Introduction

This chapter sets out the wider context of the research, introduces the topic, gives an outline of research, motivation of the research, background of the study, establishes research aims and questions, and defines the scope of the research.

Chapter 2 Multilevel framework of Six Sigma: A systematic review of literature on Six Sigma and performance

The aim of this chapter is to systematically review and synthesize the state of academic research on Six Sigma and business performance into a comprehensive multilevel framework linking management leadership, Six Sigma dimensions (organizational and project level) and performance outcome (project and organization level). The chapter clarifies that Six Sigma enhances business performance; project-by-project focus influences implementation success; and learning and knowledge creation mediates project performance.

Chapter 3 Research gap and hypotheses

The aim of this chapter is to identify any gaps in the body of knowledge of how learning takes place in Six Sigma improvement project teams and in doing so, the researcher develops four specific research questions for the study and develops a conceptual framework and eight testable hypotheses.

Chapter 4 Research process and Research paradigm

This chapter provides an introduction to the research process in management research and research philosophy and paradigms. The chapter discusses how research paradigm influences the selection of a suitable research methodology. The chapter aims to identify the nature of the research, philosophical stance of the researcher, and the methods used for the research.

Chapter 5 Research design

This chapter addresses the rationale for the choice of particular philosophies, approach, strategies, and data collection methods. This chapter outlines the research design that the researcher will follow in order to answer the research questions developed in chapter 3. The chapter explains the data collection process for the survey research and data collection plan for case study research. The chapter includes a discussion on the research quality criteria used to evaluate the overall quality of the research.

Chapter 6 **Survey data analysis: Learning behaviours and project performance**

This study investigates empirically the impact of the two learning behaviours on project performance, and the impact of four managerial factors on these behaviours and in turn on project performance.

Chapter 7 **Survey data analysis: Goal theory and Sociotechnical systems theory perspectives**

Through the lens of the goal theory, this study examines the impact of project goals on performance mediated through knowledge created in teams. The moderating role of structured methods in this mediated relationship is investigated. Sociotechnical system theory is used to explicate the relationship between technical and social aspects of project execution.

Chapter 8 **Case study Research**

The study investigates various learning behaviours, antecedents and performance consequences through a multiple case study research. The analyses of the interview data collected from senior executives, project leaders and members of the five case projects support the earlier findings of the quantitative study (chapter 6 & 7) and show some emerging factors that impact learning and performance.

Chapter 9 **Discussions, contributions, research agenda and conclusions**

This chapter explains theoretical and practical contributions from the research, quality assessment of the research, limitations of the research, and future research. This chapter gives conclusions for the research, researcher’s personal reflection on his research journey, and his future research agenda to continue this research forward.

CHAPTER 2

A MULTILEVEL FRAMEWORK OF SIX SIGMA

The chapter starts with a brief introduction of Six Sigma, its unique features, and its relationship with other quality improvement methodologies followed by a systematic review. The aim of this chapter is to review systematically and synthesize the state of academic research on Six Sigma and business performance. The chapter tracks the development of the research based on a systematic review of literature from 2000 to 2014 and synthesizes various perspectives into a comprehensive multi-level framework linking leadership, Six Sigma dimensions (organizational and project level) and performance outcome (project level and organization level), and shows that project performance is mediated through learning and knowledge creation in projects. In addition, the chapter also provides a measurement model consisting of all factors and constructs from the reviewed literature that may help researchers in their empirical research to assess the precise nature of the relationship between various dimensions of Six Sigma and business performance.

2.1 Evolution of Six Sigma

Performance is the most recurrent theme in almost all fields of management (Venkatraman and Ramanujam, 1986; Neely, 1999). The strategic objective of any organization or the goal of any strategic initiative is to improve and increase the performance level, especially the long run profits for its continued existence and growth. While there are conflicting views among scholars and academics on why organizations exist, there is no denying the fact that organizations compete one another consciously seeking advantage (March and Sutton, 1997). Competitive Advantage, and hence continued profitability relies on many operating dimensions such as business processes, internal structure and resources and how they are deployed, customer perspective of the firm on the level of satisfaction with the firm’s product/service and support, and finally, where its product/market position lies in the industry.

Note: An earlier version of this chapter was published in the *Quality Management Journal*: Arumugam, V., Antony, J., and Linderman, K. (2014). Multilevel framework of Six Sigma: Systematic review, possible extensions, and future research. 21 (4), 36-61.

A number of Continuous Improvement (CI) strategies or initiatives have been found to be adopted by organizations from time to time, such as Total Quality Management (TQM) and Just-in-time for improving the quality of the product and service through improving their manufacturing processes. These strategies help firms to survive, grow and compete in a dynamic global market (Nair, 2006; Samson and Terziovski, 1999; Kaynak, 2003). Six Sigma is one such initiatives which recently has attracted organizations of all kinds, sectors and sizes, having found its adoption in the last two decades across the globe (Antony et al, 2004a, 2004b; Linderman et al., 2003; MacAdam et al., 2005).

Coined by Motorola in 1986 as a metric for measuring defects and improving quality, Six Sigma has evolved into a robust business improvement strategy that focuses an organization on customer requirements, process alignment, analytical rigor and timely execution. Six Sigma was started as a ‘‘business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction’’ (Harry and Schroeder, 2000, p. vii).

When used as a metric, Six Sigma technically means having no more than 3.4 defects per million opportunities (DPMO) in any process in an organization. As an improvement program, it aims to reduce variation in processes, relying on rigorous data gathering and statistical analysis for identifying errors and eliminating variations to make dramatic reductions in the customer defined defect rates. The Six Sigma metric signifies driving down the variability of the process to an extent where a range of ± 6 standard deviations from the mean (centerline) falls within customer specifications. The metric translates to 3.4 defects per million opportunities (DPMO). With this ultimate objective for critical processes, the program introduces a series of practices for creating an organizational culture of scientific process improvement with continually stretched goals (Linderman et al., 2003). The target of such dramatic reductions in defect rate and the use of the Six Sigma statistic for continually inspiring improvements are seen to be a unique feature of the Six Sigma program. Scholars view that Six Sigma is an organizational phenomenon (Llorens-Montes and Molina, 2006; McAdam and Lafferty, 2004). More recently, a number of studies have focused on Six Sigma as a change management initiative (Scroeder et al., 2008; Choo et al., 2007; Buch and Tolentino, 2006; Braunscheidel et al., 2011). Six Sigma, therefore, is defined as ‘‘an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rate” (Linderman et al., 2003: p. 195). ‘‘A business improvement strategy used to improve profitability, to drive out waste, to reduce quality costs and improve the effectiveness and efficiency of all operations that meet or even exceed customer needs and expectations’’ (Antony and Banuelas, 2001). Six Sigma is not referred to as a quality tool, but rather as a business strategy (Breyfogle, 1999)

AlliedSignal was one of the early adopters of Six Sigma and the company attributed the tremendous success in process improvement executions to Six Sigma practices. Subsequently, GE adopted the program and the adoption at GE is known to be a personal initiative of Jack Welch, CEO of GE, after he heard about the success of the program at AlliedSignal from his friend Larry Bossidy, the then CEO of AlliedSignal (Eckes, 2001; Harry and Schroeder, 2000). GE incorporated Six Sigma into the fabric of their businesses and achieved results beyond the predictions of the most enthusiastic Six Sigma advocates (Pyzdek, 2003; Linderman et al., 2003). Jack Welch described Six Sigma as "the most challenging and potentially rewarding initiative we have ever undertaken at General Electric" (Breyfogle, 1999). This made Six Sigma to obtain instant popularity among industries around the globe. The number of business sectors, where Six Sigma is being applied is growing day by day, with public sectors and healthcare applications joining manufacturing, financial, information technology and higher education (Kwak & Anbari, 2006; Antony et al., 2012). The majority of the literature of practitioners and academics provides a vast number of examples, case studies and accounts of business performance improvements that have resulted because of Six Sigma (Harry and Schroeder, 2000; Pande et al., 2000; Snee and Hoerl, 2003).

Six Sigma continues to expand from its main features since it first evolved at Motorola in the mid-1980s to improve the performance of its processes (Hoerl, 2004). The perception of Six Sigma has since then changed drastically from being a statistical tool for improving quality to being a company-wide strategy for business process improvement (Antony, 2004; Kuei and Madu, 2003; Goh, 2002; Zairi, 2002; McAdam et al., 2005; Montgomery, 2005; Kumar et al., 2008).

2.2. Features of Six Sigma

Deployment of Six Sigma involves carrying out a series of improvement projects by temporary (usually three to nine months) teams (Antony, 2004; Pande et al., 2000; Pyzdek, 2003). The temporary team involves ‘‘ a set of diversely skilled people working together on a complex task over a limited period’’ (Goodman and Goodman, 1976: 494). In Six Sigma project team, members from different functions work together and collaborate temporarily and work intensively to achieve a common goal, with limited time duration and clear start and agreed on an end date. The team follows a systematic method called DMAIC (Define, Measure, Analyze, Improve and Control) to solve problems and improve processes. Team members are drawn from different and diverse functions, and they typically work on a part-time basis, while the project leader, who is trained and certified in Six Sigma methodology, works full-time. These specialists are called as Master Black Belts, Black Belts, Green Belts or Yellow Belts, depending upon the training levels they undergo and the skills they attain. The DMAIC stipulates that its five interlinked phases should be carried out rigorously and systematically and that project reviews must be conducted at the end of each phase by the senior management team, while the financial and strategic benefits are validated by an auditor at the end of the project (Pande et al., 2000).

The project starts by defining what needs to improve and what is important to the customer in the Define phase. These *Critical to Quality* characteristics are measured and analyzed, and based on the baseline performance, improvement goals are set. Six Sigma is known for employing challenging goals, sometimes as high as a 10-fold increase from the baseline performance (Linderman et al., 2003; Pande et al., 2000). In the Measure phase, rigorous data collection is done, while, in the analysis phase, data analysis is carried out to identify the contributing factors that influence the *Critical to Quality* measure and in turn process performance. Subsequently, in the Improve phase, the team determines an optimum solution and implements its recommendations. Finally, in the Control phase, the team takes control actions to sustain the gain obtained and finally the improved process is handed over to the process owners.

The DMAIC method guides the project team through the application of various tools and techniques in order to identify process input variables that contribute to the process outcome. The team then modifies the process to gain improvement in process capability, leading to enhanced product quality. This standard framework is designed to assure that the project stays focused on its goal; it further facilitates the involvement of team members through a shared understanding of its steps. Through a series of such projects, organizations systematically change their business processes or routines and achieve improved business performance.

2.2.1 DMAIC methodology

Define Phase involves in identifying Critical to Characteristics (CTQs) that are driven by the Voice of the Customer (VOC). It develops team charter and finally defines a high-level process map connecting the customer to the process and identifies the critical inputs and requirements.

Measure Phase to gather information about the current situation, to measure baseline current process performance, and to determine the problem areas.

Analyze Phase involves establishing process capability with the help of capability indices, defining performance objectives by benchmarking and identifying the sources of variation by performing analysis of variance and hypothesis testing. Based on the analysis, root causes of variations and their impact on the output variables are identified.

Improve phase implements an optimal solution that is identified and recommended that addresses the problems.

Control Phase to put in place systems to monitor both the process output and the factors that influence output variation, thus ensuring that results achieved in the previous phase are sustained.

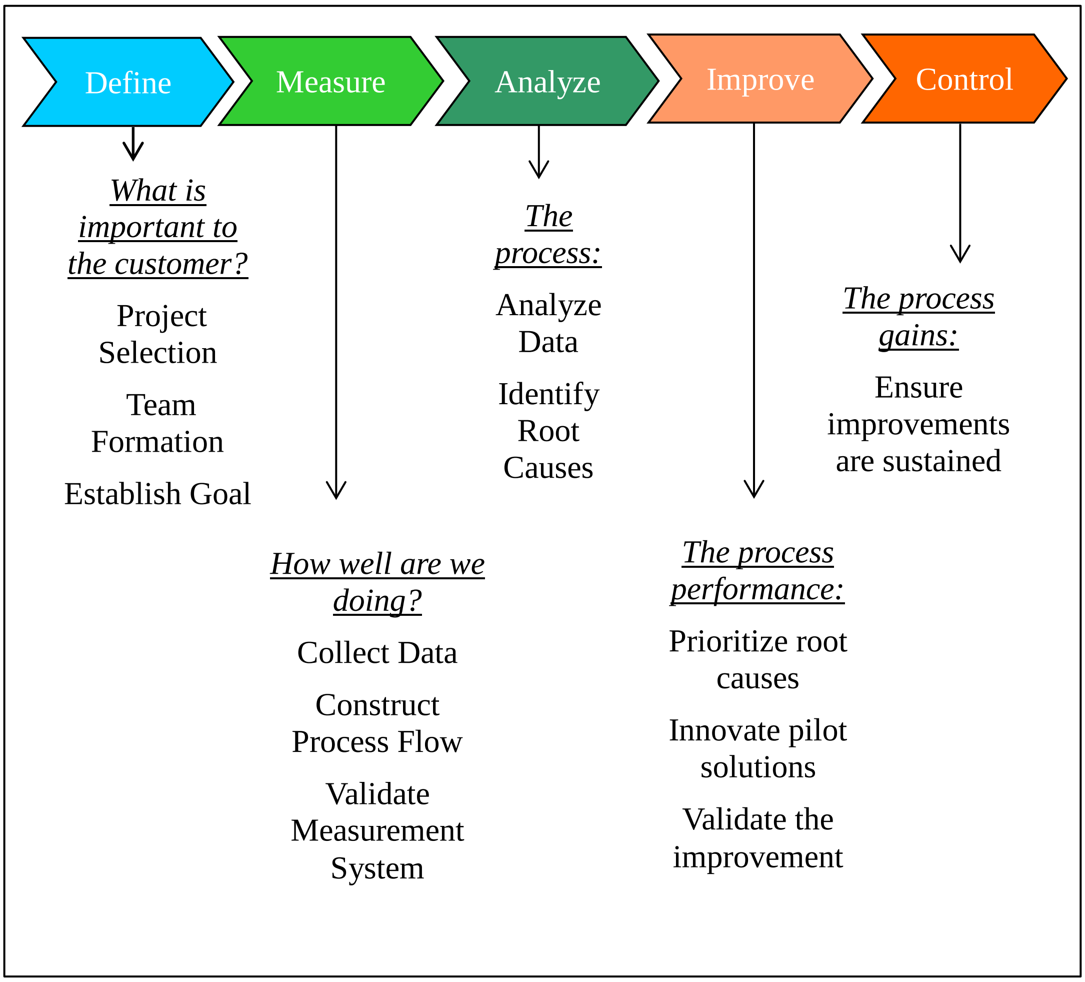


Figure 2.1 DMAIC methodology

The challenge in CI initiatives and more particularly in Six Sigma implementation lies in creating the infrastructure to coordinate improvement projects (Choo et al., 2007). It depends largely on motivating employees, training them and coordinating their efforts in projects as well as implementing changes resulting from improvement projects (Anand et al., 2009). For process improvement efforts to be effective, management needs to ensure, through the use of appropriate practices, that in addition to the means and authority to participate in improvements, employees have a sustained level of interest toward seeking process improvements (Upton, 1996). Management through Six Sigma framework ensures employees' sustained level of interest in participating in Six Sigma deployment. Management, for example, ensures strict adherence of the use of structured method such as DMAIC or its variants, establish relevant resource and infrastructure for deployment and project execution, including trained specialist for leading the projects, and constantly involved in project selection and execution appropriately.

There are striking differences compared to previous quality improvement programs in the way Six Sigma is structured in organizations and the way its projects target improvements. Some of the important features of Six Sigma are given below (Antony et al., 2008; Harry and Schroder, 2000; Pande et al., 2000; Goh, 2002).

Framework: Provides a framework for improving quality. Six Sigma prescribes a structured method for comprehensive implementation of principles and practices that have been only loosely suggested in previous CI programs. DMAIC incorporates relevant statistical tools for real-world application. It ensures focus on proactive and data-based decision making and utilizes hardware and software of information technology for problem-solving and database for project repository.

Customer focus: Gives the impetus for performance improvement with respect to customer expectation. Strategic improvement projects are selected and executed that satisfy customers. Six Sigma stresses project-by-project focus for its implementation; The project has a concrete objective, beginning, and an end, and follows planning, review and learning

Common metrics to compare Performance: Creates a quantitative basis for performance comparisons, from a single process to a cross-industry process. Common performance metrics: DPMO (Defect per Million Opportunities), Sigma level, etc.

Special and intensive training and role structure: Training is imparted to employees in varying degrees in tools and techniques. The level of training depends upon their responsibilities toward deployment (Deployment Champion, Mentor and trainer, project leader and team member). Six Sigma has been very successful in integrating both human aspects (culture, training, customer focus, etc.) and process aspects (process capability, variation reduction, method etc.)

Practices: The Six Sigma program included several existing TQM practices such as cross-functional teams and customer involvement. Improvement focuses on a project-by-project. Projects are selected based on strategic criteria. Project reviews are conducted during project execution, and financial gains for each project are evaluated and established. The magnitude (usually challenging goals, sometimes as high as 10-fold) and the type of goals also have psychological implications for team members to put more efforts (Linderman et al., 2003). Six Sigma places a clear focus on bottom-line impact. Gain from the project is audited and approved by competent financial authority. No project is undertaken unless the project team estimates the saving potential of the project

2.3 Critical review of Six Sigma

In spite of the popularity that Six Sigma has earned during the last two decades, there are claims and counter claims regarding its status as a strategic initiative. There are a number of viewpoints and theoretical discussions of Six Sigma in the literature and the debates primarily focus on the following four areas.

1. Is Six Sigma merely a quality improvement tool or Strategic change initiative?
2. Its applicability to service processes
3. Whether Six Sigma Supports or stifles innovation in organizations
4. Its applicability to small and medium industry

2.3.1 Strategic initiative or a quality improvement tool?

The main focus of the discussion in this stream is whether Six Sigma is really a strategic initiative or just a quality improvement tool. As the main theme of Six Sigma is that by focusing on measuring and reducing variations in processes, it is thought that Six Sigma is only a quality improvement process employing technology-based statistical process control methods, rather than a broad business improvement approach. With the advent of global competitiveness, ever-increasing integration of quality and business strategy have resulted in an alignment of organizations around its business processes and overemphasizing more autonomy into the hands of the people who do the work and improvement activities (Zairi, 1999). This changed scenario, coupled with the success stories of Six Sigma deployment in organizations across the globe showing long-term profitability has led to view Six Sigma as a business strategy, rather than a mere quality improvement tool. Scholars, therefore, assert that Six Sigma is neither a fad nor just another quality initiative, but a distinct quality improvement initiative (Kumar et al., 2008). ‘‘Six Sigma has been very successful-perhaps the most successful business improvement strategy for the last 50 years” (Montgomery, 2005). Scholars have begun to view Six Sigma as a broader change management philosophy from the earlier view of Six Sigma as a quality tool (Buch and Tolentino, 2006; Nonthaleerak and Hendry, 2008).

McAdam and Lafferty (2004) examine how Six Sigma affects an organization and its employees at various levels in a high-tech organization and suggest that although Six Sigma is rooted in the mechanistic perspective, there is an increasing dynamic to that of a broader, more organic and strategic approach. They conclude that ‘‘Six Sigma has some way to go before it is fully accepted as a broad change philosophy, applicable across a range of organizational types’’ (McAdam and Lafferty, 2004: 545-546). This view is also supported by others (Henderson and Evans, 2000; Goh, 2002; Kuei and Madu, 2003; Schroeder et al., 2008). Schroeder et al. (2008), for example, claim that Six Sigma helps an organization become more ambidextrous by providing a switching structure (improvement specialists) that allows the organization to act more organically in coming up with new improvement ideas and operate more mechanistically when implementing them (Schroeder et al., 2008). Henderson and Evans (2000) suggest that operational Six Sigma can create an upward pressure for a more strategic based approach. Though there is a strong support in the literature for Six Sigma being considered as mechanistic, a growing number of papers have recently claimed that Six Sigma has indeed been a strategic change initiative (Antony et al., 2008; Pande et al., 2000).

2.3.2 Six Sigma and service processes

Statistical thinking and methodologies constitute the backbone of Six Sigma. It was first applied in manufacturing processes in which defects can be clearly defined, as well as measured, and the extent of improvement achievable is quantifiable. As the use of quantifiable measures is emphasized in Six Sigma, it is thought that Six Sigma is most suited to manufacturing organization and only a limited extent to service organizations. Although Six Sigma started its adoption in manufacturing organizations, over time, it has undergone significant changes as evident from extant literature. Primary objective changed from reduction of defects to cost reduction and to creating value to customers and organizations (Antony, 2007). There is increasing evidence of its application in service sectors and the literature show empirical evidence on the successful deployment of Six Sigma in health care, banking, and call center services (Hensley and Dobie, 2005).

Most of the service processes do not generate data and hence the availability of data for the project are very rare. Although most of the case studies use tools and techniques to only a limited extent, the benefits obtained from the projects are found to be enormous. This is due to the fact that these projects use the structured method that guide project teams to focus on the project objectives and apply appropriate tools that are relevant to the project in hand. Other services such as education and hospitality are also beginning to see six sigma applications. Most of the academic studies, including case studies are from healthcare sectors and less from other service sectors (Chakrabarty and Tan, 2007).

Apart from the financial benefits, other benefits brought out from Six Sigma deployment in service sectors include, increase in customer satisfaction, and employee morale; improvement in cross-functional teamwork across the organization, and consistent level of service; and increased awareness of problem solving tools and techniques (Kwak and Anbari, 2006; Antony, 2006; Sehwall and DeYong, 2003). The task of improving service in organizations is complex as it involves multiple fronts such as, technology, service systems, employee selection, training and education, and reward systems (Berry and Parasuraman (1997). The challenges are more due to the special characteristics of service quality. Some of features of service quality that are differentiable from the product quality are:

- Service quality is more difficult for the consumer to evaluate than product quality
- Service quality perceptions result from a comparison of consumer expectations with actual service performance
- Quality evaluations are not based solely on the outcome of a service, but also involve evaluation of the delivery process (Ghobadian et al., 1994).

Recently, a number of articles have focused on the importance of six sigma for services and the challenges faced by service processes (Biolos, 2002; Hensley and Dobie, 2005; Chakrabarty and Tan, 2007; Antony et al. 2007; Kumar et al., 2008). Though six sigma delivers what transactional process quality, it only inadequately addresses service quality requirement. There are differences between customer's perceived service and their expected service that produces satisfaction or dissatisfaction. This could be caused by the non-synchronization of factors such as, customer expectation, organization’s understanding and conceptualization of customer expectations, service specification and actual service delivery (Parasuraman et al., 1985, 1988, 1991; Zeithaml et al., 1988, 1996; Berry and Parasuraman, 1997). The current level of tool kits in six sigma lacks in tackling service process quality enhancement as it primarily focuses on the delivery process in physical terms (e.g., Response time, processing time, and cost of delivery), and not on the behavioral terms. Secondly, the nature of the service processes is so different from industry to industry, such as standardized service (banking and telecommunications), non-standardized service (legal, architecture, entertainment, etc.) that quality requirement varies. Six Sigma training and educational programs need to adapt their curricula to service operations (Nakhai, and Neves, 2009).

Scholars are of the view that the full potential of Six Sigma in services is yet to be realized (Nakhai and Neves, 2009; Chakrabarty and Tan, 2007). They suggest that belts are not only to be trained in six sigma tools and concepts, but also in service quality ideas and methods as Service quality training is vital for the successful development of six sigma in services (Nakhai and Neves, 2009).

2.3.3 Six Sigma and innovation

There is a limited debate in the literature on the capability of Six Sigma in facilitating innovation. Further, these discussions have conflicting arguments in regard to this relationship. Most of these papers are theoretical in nature (Parast, 2011; Hoerl and Gardner, 2010), and only a few studies show empirical evidences on these relationships (Antony et al., 2014; Sony and Naik, 2012). Innovation can be defined as anything new or novel about the way a company operates or the products it produces (Hill and Jones, 2001). Damanpour (1991) defines innovation as adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization. Innovation, thus, implies novelty. Innovation includes advances in the products, production processes, management systems, organizational structures, and strategies developed by a firm.

Two types of innovations are central to the innovation studies-product versus process innovation, and incremental versus radical innovation (Abernathy and Utterback, 1988; Tushman and Nadler, 1986; Zairi, 1995). Incremental innovation can be related to feature improvements in existing process or product/service-relevant to the existing consumer, continually making the product/service more competitive, and focuses on cost reduction. Innovation still allows existing products to stay competitive. Radical innovation relates to quantum leaps in processes or product. It helps an organization to explore and develop new capabilities. Developing new business strategies or developing a completely new and novel product makes the organization unique and enhances Competitive Advantage (CA). Radical innovation results in a product that is so superior that existing products are rendered noncompetitive, and may create new opportunity and new market. Both are necessary for the long term survival of an organization, as organizations have to innovate to create the business, and they have also to continuously improve their processes to stay in business.

Benner and Tushman (2002) are of the view that process management can drag organizations down and dampen innovation as people may focus on efficiency rather than on innovation. They further state ‘‘exploitation’’-building on a firm’s existing knowledge-‘‘crowds out exploration.’’ It is argued that more focus on process management activities will lead to exploitation at the expense of exploratory innovations. As Six Sigma focuses on process management, the primary question then arises: can Six Sigma be a specific resource that enhance innovativenss of organizations? Conflicting arguments are found in the literature in regard to this relationship. It is argued that Six Sigma lacks creativity and innovation as it is not demanded by the structured process employed by the organization (Goh and Xie 2004). The authors base their arguments on the fact that the goal in Six Sigma deployment is to achieve only a target Sigma level or variation levels of a process or product as against achieving attractive quality that delights the customer (Goh and Xie, 2004). Some scholars are also of the same view based on the notion that Six Sigma project team follows a rigid sequence of steps in DMAIC employing rigorous and analytical methods. Six Sigma is limited to, continuous improvement rather than radical change (Anand et al. 2009) as it does not involve any behavioural or change processes required for radical innovation (Parast 2011). Parast, (2010) argues that the Six Sigma methodology impedes the ability of the firm for radical innovation, and the program does not guarantee a sustainable CA for the firms due to its focus on existing processes, products and customers. Hoerl and Gardner (2010) and Montgomery and Woodall (2008), on the other hand, argue that a considerable level of creativity needs in each phase of DMAIC cycle-to think through how to approach each phase of DMAIC, to select the specific tools, and how to interpret the statistical results. In the Improve phase, for example, the project team turns to creative thinking while contemplating the specific changes that can be made in the process and other things that can be done to have the desired impact on the process performance (Montgomery and Woodall (2008).

Scholars argue that Six Sigma projects to improve organizational processes and routines for improving efficiency within an existing technological base of the organization (Benner and Tushman, 2003), and thus continuous and incremental change. It is not designed to develop the best ideas for radically new products and services and is not the path to disruptive innovation (Hoerl and Gardner, 2010). Parast (2011) posits that Six Sigma program positively impacts incremental innovation, which is also supported by the explorative study undertaken by Antony et al. (2014). The study points out that Six Sigma fosters an innovative culture in the organization, and thus the development of innovation capability. The study also reveals that organizations that provide service offerings have greater potential for innovation by Six Sigma implementation. Incremental innovation is thus an integral part of the DMAIC process.

Organizations seeking long-term success will need a balanced approach to business improvement that includes problem-solving, continuous improvement, and also systems to identify opportunities for disruptive innovation (Hoerl and Gardner, 2010). Six Sigma being a continuous improvement strategy encourages changes and creative thinking about the people who are involved in improving processes. Cross functional flow of information and knowledge becomes the driving force of organizational innovation (Wiklund and Wiklund, 2002). Some of the elements of Six Sigma projects such as multidisciplinary members, dedicated project leader, inter-functional communication and co-operation, qualifications and know-how of the project leader, team autonomy and responsibility for the process are some of the generic characteristics that improve innovativeness (Ernst, 2002), and hence Six Sigma is a resource for innovation. The creativity of an individual is the root of any innovation, and creativity sets in motion the innovation process of getting new ideas developed into a product, process or service. Innovation is a function of individual creativity, social process and contextual factors. Comparing innovation capability of TQM and Six Sigma, scholars suggest various factors that potentially impact innovation in organizations deploying Six Sigma. These include, Team diversity, project selection, customer focus, belt system, and process management (Antony et al., 2014; Sony and Naik, 2012). Moore and Tushman (1982) contend that improving existing products/process and development of new products/process can both be considered manufacturing innovation. Improving existing process and developing new process can both be considered manufacturing innovation (Moore and Tushman, 1982). Both of these involve new ideas and consequent changes and Schroeder et al., (1989) suggest that implementation of new ideas or changes, both large and small, which have the potential to contribute to organizational objectives, can be considered as innovation (Schroeder et al., 1989). Therefor, Six Sigma can be a resource for innovation, and the innovation is incremental.

2.3.4 Six Sigma and Small and medium Enterprises (SMEs)

Small and medium Enterprises are not ‘little big industries’ and are not scalar versions of larger industries, rather they operate in a different domain (Welsh and White, 1981), and they are distinct entities with specific management strategies, operating principles, and having specific viewpoints and interpretations of improvement initiatives. They lack resources, time and finances, and skills that are available with bigger industries. Scholars argue that the interpretation of Six Sigma in SME context cannot be assumed to be a scaled down version of Six Sigma applied to large industries, as SMEs operate in a different and specific context (Cope, 2005; Perren and Ram, 2004). Researchers and practitioners have developed models and frameworks that are suitable for small industries (for example, Thomas et al., 2009; Kumar et al., 2011). Although practitioners argue that there is nothing inherent in Six Sigma that makes it more suitable for large companies, the documented evidence of Six Sigma implementation in small and medium enterprises (SME) is sparse in the literature (Antony et al., 2008). The majority of the papers on implementation in SMEs comes from Europe, notably from the UK (Timans et al., 2012; Antony et al., 2008; Kumar, 2007; Kumar and Antony, 2009; McAdam et al., 2011). Antony (2008), Chen et al. (2010) and Thomas et al. (2009) argue there is a need for further research in relation to the application of Six Sigma in smaller firms.

2.4 Deployment approaches

Industry witnesses different styles of Six Sigma deployment:

(1) Strategic deployment, in which organizations launch Six Sigma as a companywide strategic change management. This involves accompanying changes in culture. It takes a longer period for fully maturing and also depends on the company size and reach. Usually, it takes three to four years to embrace the strategy throughout the organization. Deployment includes company-wide Six Sigma training, creating enough number of specialists at MBB, BB and GB levels and company–wide strategic deployment. Examples: GE, AlliedSignal, Motorola (Harry and Shroeder, 2000); SKF (Schon, 2006).

(2) Deployed as an improvement program. Six Sigma is deployed in some specific area or regions of the business or selective business units or functional units. Primary reason could be to improve specific areas of business. The implementation is extended subsequently to other business units (Nanthaleerak and Hendry, 2008).

(3) Small and medium companies that target to improve some problematic areas. Companies execute improvement projects using Six Sigma methodologies, tools, and techniques. Mainly this approach is used in call centers, small and medium manufacturing organizations, hospitals, and public sector organizations (Antony, 2007; Antony et al., 2005; Laureani, Antony, & Douglas, 2010).

The next section discusses a systematic review of the literature to synthesize the state of knowledge on Six Sigma and performance.

2.5 Systematic Reviews

Systematic reviews differ from traditional narrative reviews by adopting a replicable, scientific and transparent process that aims to minimize bias by providing an audit trail of the reviewers' decisions, procedures and conclusions (Cook, Mulrow and

Haynes, 1997; Tranfield, Denyer, and Smart, 2003). Systematic reviews adhere closely to a set of scientific methods that explicitly aim to limit systematic error (bias), mainly by attempting to comprehensively identify, appraise and synthesize all relevant studies in order to answer a particular research question (Petticrew and Roberts, 2006). A comprehensive, unbiased search is one of the fundamental differences between a traditional narrative review and a systematic review. It provides the most efficient and high-quality method for identifying and evaluating extensive literature (Murlow, 1994). Multiple reviewers are engaged in comparing and reconciling each study or paper. Systematic reviews provide a means for practitioners use the evidence provided by research for their informed decision-making processes. Systematic review has its origin from positivistic paradigm (Tranfield et al., 2003). ‘‘Positivists seek cause-effect laws that are sufficiently generalizable to ensure that a knowledge of prior events enables a reasonable prediction of subsequent events…. Because positivists see knowledge as accumulating, they have been more interested in developing approaches to research synthesis than have interpretivists.’’ (Nobilt and Hare, 1988:12).

This research adopts systematic review procedures outlined by Tranfield et al. (2003), comprising three stages of the review process: planning, execution, and reporting. At the planning stage, the researcher defined the objective of the research and the review protocol, including explicit descriptions of the various steps in the review process, the key data collection method, the search strategy for identification of relevant studies, and inclusion and exclusion criteria. These explicitly aim to limit systematic error and bias (Petticrew and Roberts, 2006).

Execution stage includes collection and organization of data, data processing and classification, and data synthesis. Data collection is done by using a predefined selection algorithm using predefined search strings. The researcher searched for published research from 2000 to 2014. The year 2000 is chosen as the starting year as the review finds that academic focus on Six Sigma research started from that year onwards. In order to ensure comprehensive coverage of the literature, the researcher considered the following three criteria for choosing the journals: (1) Include journals in business and management category, as previous reviews identified some mainstream management and business journals that published Six Sigma research;

(2) Include Journals focusing quality and process management research, as Six Sigma belongs to these research streams; and (3) Include peer-reviewed journals that exclusively focus on Six Sigma and related research. Conference proceedings, academic dissertations, textbooks and unpublished working papers were excluded. The review was limited to double-blind peer-reviewed journal articles, as the published journal articles can be considered as valuable knowledge (Armstrong and Wilkinson, 2007; Podsakoff et al., 2005; Ordanini et al. 2008), and influential journals tend to shape theoretical and empirical work (Furrer et al., 2008).

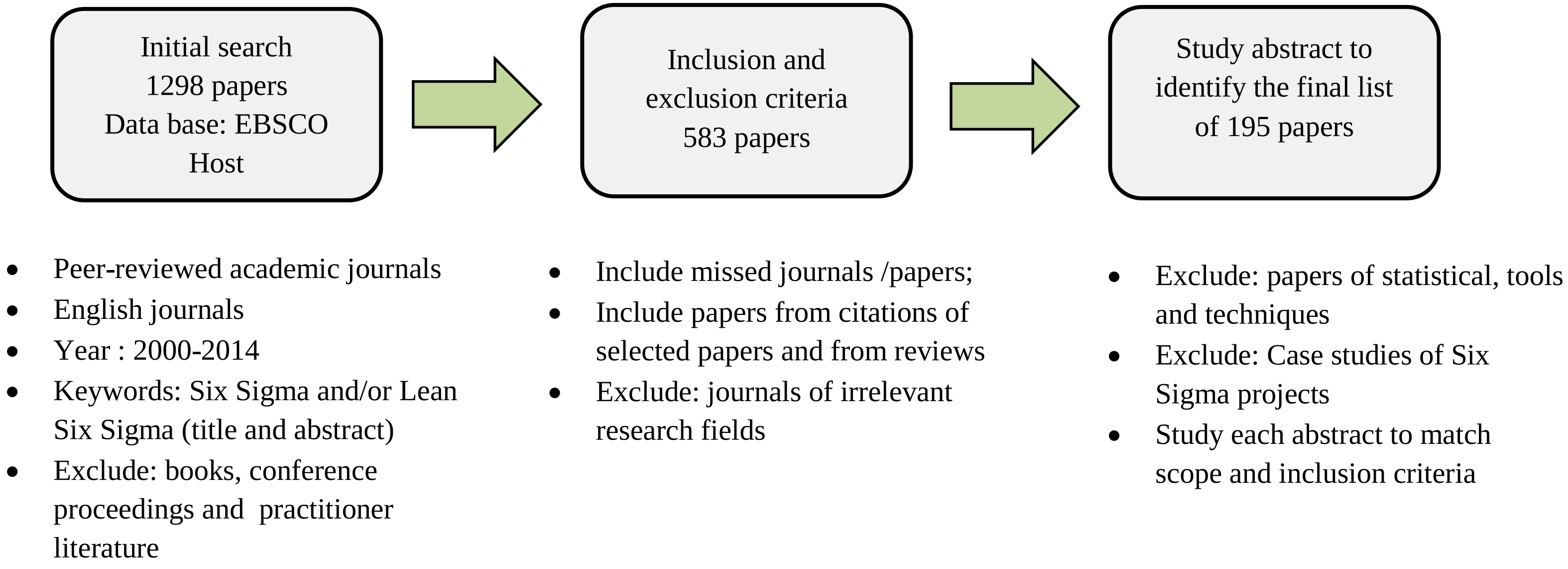
The list of peer-reviewed journal articles were obtained from EBSCO host and Emerald Insight as they cover the entire management and quality related fields. The researcher began his search by identifying publications with ‘Six Sigma’ and ‘Lean Six Sigma’ as keywords as these words reflect the scope of review. These keywords were targeted to ‘title’ and/or ‘abstract’ only. Other criteria used in the initial search include English language, peer-reviewed academic journal, and the period from 2000 to 2014. The initial search resulted in 1298 papers. Figure 2.2 shows the selection procedure.

The papers from journals focusing on areas other than management were excluded. Further search in key journals was used to supplement the initial search to identify articles that might have missed in the initial search. In order not to miss any relevant articles that are within the inclusion and exclusion criteria, the researcher cross-checked with earlier reviews and included those papers that are within the criteria. Manual searches of numerous reference lists of the selected papers were also carried out to identify any additional relevant papers that fall under the selection criteria. The search ended up with 583 papers with these inclusion and exclusion criteria.

The list was then filtered for articles linked to the literature review, six sigma/Lean Six Sigma concepts and theory, critical success factors, case studies and performance. Further filtering was done to exclude the following: papers dealing with Six Sigma models for implementation; papers dealing with statistical domains; and papers dealing exclusively on tools and techniques of Six Sigma and industrial case studies demonstrating Six Sigma improvement projects. Thus, the researcher tried ‘‘to retrieve everything of relevance, while leaving behind the irrelevant’’

(Petticrew and Roberts, 2006: pp. 81). By going through each abstract, finally, the researcher identified relevant articles to match the inclusion criteria and scope of the study and this systematic and rigorous selection identified a total of 195 papers appeared from 2000 to 2014 in 30 peer-reviewed journals. The search process had been sufficiently comprehensive to provide a fairly representative sample of the literature. Table 2.1 shows the list of journals and the number of articles from each journal.

Next part of the process is a data analysis followed by synthesis. Since the objective of the study is to review and synthesize the literature rather than to consolidate the findings empirically, the researcher limit the methodology to descriptive and qualitative analysis. The interpretative synthesis (Dixon-Woods et al., 2006) was carried out using findings from studies to develop additional concepts then. It involves an in-depth qualitative analysis of each research study selected for review inclusive of all aspects of the research process, related findings, and interpretations made from the primary research (Bronson and Davis, 2012). Finally, an overall explanation of these findings through a multi-dimensional framework along with future research directions is provided.



- Peer-reviewed academic journals
- English journals
- Year : 2000-2014
- Keywords: Six Sigma and/or Lean Six Sigma (title and abstract)
- Exclude: books, conference proceedings and practitioner literature

- Include missed journals /papers;
- Include papers from citations of selected papers and from reviews
- Exclude: journals of irrelevant research fields

- Exclude: papers of statistical, tools and techniques
- Exclude: Case studies of Six Sigma projects
- Study each abstract to match scope and inclusion criteria

Figure 2.2 Selection and review procedure

Table 2.1 List of reviewed Journals and the number of articles (Six Sigma and Performance)

Journal	Number of articles
International Journal of Six Sigma and Competitive Advantage	28
International Journal of Quality & Reliability Management	24
Total Quality Management & Business Excellence	23
TQM Journal (earlier known as TQM Magazine)	20
International Journal of Lean Six Sigma	20
Journal of Operations Management	11
Quality Management Journal	6
Business Process Management Journal	5
International Journal of Operations & Production Management	5
International Journal of Production Research	5
International Journal of Production Economics	4
Journal of Manufacturing Technology Management	4
Quality and Reliability Engineering International	4
International Journal of Health Care Quality Assurance	4
Operations Management Research	4
Quality Engineering	4
International Journal of Productivity and Performance Management	3
Benchmarking: An International Journal	3
Managing Service Quality	3
Measuring Business Excellence	2
Journal of the Operational Research Society	2
Industrial Management & Data Systems	2
Managerial Auditing Journal	2
IEEE Transaction on Engineering Management	1
Decision Sciences Journal	1
Management Science	1
International Small Business Journal	1
International Journal of Organizational Analysis	1
Production Planning and Control	1
Technovation	1

Total number of Journals 30

Total number of articles 195

Year of publication: 2000 to 2014

2.5.1 Data analysis and results

Of the 195 papers in the review, empirical papers represented the largest part with 53%. Descriptive papers represented 21%, conceptual papers 18% and review papers 8%. Figure 2.3 shows the breakdown of articles by paper type.

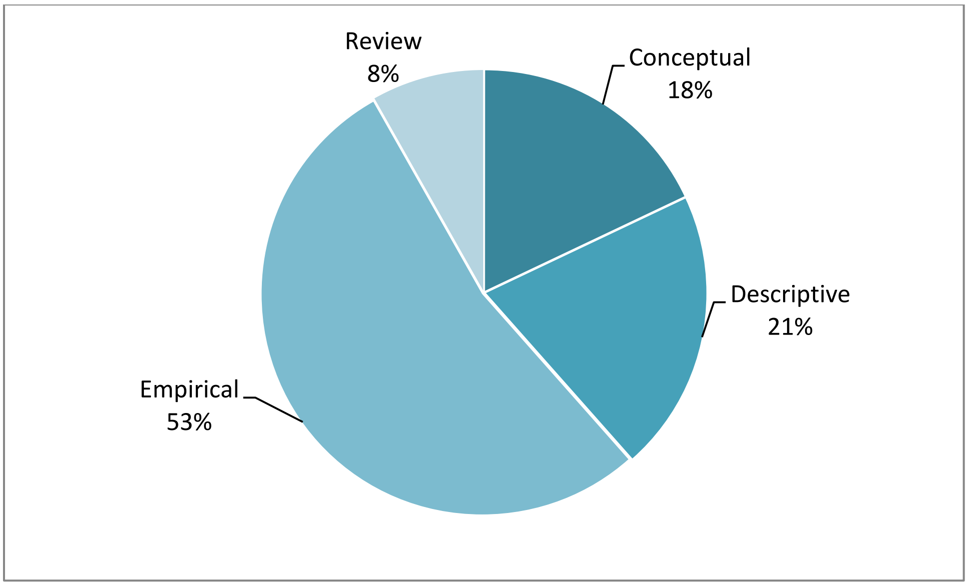


Figure 2.3 Breakdown of articles by paper type

The researcher reviewed the literature to identify the major themes. The areas studied were features of the study, sample characteristic, context, methodological quality, emergent themes, links to other concepts and theories, and key results (Tranfield et al., 20003). The majority of earlier studies also focuses on methodologies, tools and techniques, critical success factors, and case studies (Nonthaleerak and Hendry, 2006). A growing number of recent publications, however, deal with theory building and the performance impact of Six Sigma, showing an increased academic acceptance of the Six Sigma phenomenon and its impact on business performance (Linderman et al., 2003, 2006, 2010; Choo et al., 2007; Braunsceidel et al., 2010; Schroeder et al., 2008).

Since the main objective of the review was to provide a broad theoretical understanding of Six Sigma and its relationship to performance, formulate a research framework, and identify the gap, the researcher classified the selected papers on the basis of their research focus, leaving other classification methods such as research methods, and application sector (manufacturing vs. Services). Accordingly, the researcher classified each of the selected papers, other than the review papers, into one of the following categories by studying each in detail: (1) focusing on Six Sigma implementation: Critical Success Factors and Six Sigma implementation scheme; (2) comparing Six Sigma with other quality management (QM) initiatives, and enhancing its features and capability by integrating with similar initiatives; (3) explaining the phenomenon through various management theories borrowed from other management fields; and (4) investigating the performance consequence of Six Sigma. Some of the papers fell into more than one category, as they focus on more than one area. For example, some papers focus on CSFs and performance. Collectively, these four streams to help advance our understanding of the Six Sigma phenomenon.

2.5.1.1 Critical Success Factors and implementation scheme

Rocket (1979) defines Critical Success Factors (CSFs) as "the limited numbers of areas in which results, if they are satisfactory, will ensure competitive performance for the organization." In Six Sigma context, they represent the essential ingredients without which there is very little chance of successful outcomes. Drawing on studies from TQM literature, the majority of the earlier papers in this stream of research focus on the theoretical conceptualization of various CSFs (Coronado and Antony, 2002). The majority of empirical studies focuses on identifying theses CSFs through case studies and, to a limited extent, through survey research (Antony and Banuelas, 2002; Antony and Fergusson, 2004; Antony et al., 2008; Manville et al., 2012; Brun, 2010). Management commitment and support, creating and nurturing conducive culture that sustains Six Sigma, training, the selection and prioritization of projects, improvement specialist, structured approach in project execution, customer focus, tools and techniques, linking Six Sigma to Business strategy, focus on metrics, linking Six Sigma to human resources management (HRM) and data based decision making are some of the CSFs found in the earlier literature. Culture has an influencing role on effective implementation, while the relationship between culture and Six Sigma is also well acknowledged in the reviewed literature (Antony and Banuelas, 2002; Zu et al., 2009; Cho et al., 2011; Llorens-Montes and Molina, 2006; Motwani et al., 2004). Introduction and deployment of Six Sigma involves and results in changes in the people's mindset, as they need to think differently and act differently. The people are expected to manage with facts and data which demand a paradigm shift. Eckes (2002) argue that the cultural change needs to be considered if Six Sigma is to last beyond the first series of projects (Eckes, 2002). Demonstrating the need for Six Sigma, shaping the vision of a Six Sigma culture, identifying and managing the resistance to change, changing the system and structure of the organization, all of which are influenced by the senior management team, and in turn it affects the effectiveness of deployment (Antony et al., 2007; Chakravorty, 2009b; Zu et al., 2009). Studies also establish that Six Sigma changes the culture of an organization (Thawani, 2004). Collectively, these factors can be considered to represent the multidimensional nature of Six Sigma strategy.

By investigating the nature of various CSFs and their deployment, scholars have recently started investigating how the effective implementation of these CSFs leads to the effective deployment of Six Sigma (Chakravorty, 2009a, 2009b; Nonthaleerak and Hendry, 2008; Antony et al., 2005; Zu et al., 2008; McAdam and Lafferty, 2004). The studies in this stream help identify a successful implementation scheme and as well as those factors that lead to deployment success.

A review of the literature suggests a number of such success factors that are critical to the successful implementation of Six Sigma. Table 2.2 shows various CSF and their appearances in key references. It can be seen that there is a varying degree of frequency that each of the items selected is considered in the studies reviewed. Management support and commitment, Six Sigma training, organizational infrastructure and belt system (role structure), Six Sigma tools and techniques including structured methods such as DMAIC or its variants, customer focus, project selections, cultural change, linking Six Sigma to business strategy, are included in most of the studies. Table 2.3 displays these CSFs, their key characteristics and literature references.

An increasing number of the recent studies also verify the CSFs through empirical investigations either in single case studies or through survey research (e.g., Aboelmaged, 2011; Jayaraman et al., 2012; Cho et al., 2011; Manville et al., 2012; Zu et al., 2008; Antony and Benalaus, 2002; Antony et al., 2005, 2007, 2008, Timans et al., 2012; Yang et al., 2008; Schon, 2006; McAdam and Lafferty, 2004; Revere et al., 2006). A few recent papers through single and multilevel case studies have looked into both key determinants of successful deployment of Six Sigma and the factors that impede adoption success and how they vary with contextual factors such as organizational level, company types, and size (Does et al., 2002; McAdam and Evans, 2004; McAdam and Lafferty, 2004; Nonthaleerak and Hendry, 2008; Firka, 2010).

The comprehensive review has identified some new CSFs and also brought out micro-level details of the existing CSFs. A lack of management commitment due to shift in focus and priorities (McAdam and Evans, 2004; Timans et al., 2012; Antony et al., 2004), the inadequate involvements of management in project selection, poor resource allocation, and management's inadequate involvement during the project life cycle (Nonthaleerak and Hendry, 2008) are some of the factors that adversely affect deployment success. The review reveals that the correct definition or sequencing of Six Sigma projects (Chakravorty, 2009b), vague definition of expectations, or poorly defined sequencing of project (Szeto and Tsang (2005) can also greatly jeopardize the success of Six Sigma. Data non-availability for projects, (Antony et al., 2007; Chakravorty (2009b), an inadequate level of cultural readiness, and insufficient knowledge sharing capability among project team members are also found to inhibit deployment success (Rajamanoharan and Collier, 2006). Six Sigma coach availability for projects, their nature of work such as full time or part time, differential training contents that match the organization's business sector, such as manufacturing and services, failure to match the training level, and the capability and skill level of trainees who can absorb the skill have emerged as some of the new factors from recent research (Nonthaleerak and Hendry 2008; McAdam and Evans, 2004).

Upon reviewing the various CSFs, it became apparent that they could be meaningfully organized into two groups: those related to managerial actions and those pertaining to project level activities. The former refers to actions taken by senior management team, and the latter relates to actions taken by project teams.

2.5.1.2 Six Sigma and other initiatives

Since Six Sigma has evolved and has been led by practitioners, researchers try to bridge the gaps between theory and practice that is evident from the growing number of publications documented in QM literature, and see whether Six Sigma is in fact a separate entity of its own or a more specific case of TQM. All papers have compared in terms of one or more of principles, values, methodologies and tools of each initiative and conclusions significantly differ among the papers.

Two schools of thought emerge from this strand. The first school of thought asserts that Six Sigma is different from TQM (Andersson et al., 2006; Black and Revere, 2006; Dahlgaard and Dahlgaard-Park, 2006; Ferng and Price, 2005; Furterer and Elshennawy, 2005; Green, 2006) This stream suggests that it is solely an operational improvement methodology (Dasgupta, 2003; Go & Xie, 2004) or a more holistic strategic initiative that improves business performance (Antony & Banuelas, 2002; Kumar et al., 2008; Kwak & Anbari, 2004; Zairi, 2002; Kue & Madu, 2003; Goh, 2002; Breyfogle, 1999; van Iwaarden et al., 2008). Six Sigma focuses on process improvement through a structured approach by using the sequential application of many proven tools and techniques by improvement specialists. Some of the proponents of this stand increasingly recommend an integrated model comprising both Six Sigma and TQM (Yang, 2004; Klefsjo et al., 2006). Since Six Sigma was not designed to be a holistic quality system (Hoerl, 2004), some scholars see it within the larger context of Total Quality Management (Klefsjo et al., 2001). Schroeder et al. (2008) by using a grounded theory approach, assert that implementation mechanism of Six Sigma differs from TQM in four areas: focus on financial results, adherence to structured method, use of specific metrics and use of full-time improvement specialists. Researchers also combine and extend the Six Sigma methodology along with other improvement strategies like TRIZ, and Lean manufacturing (Arnheiter and Maleyeff, 2005) that seek to enhance effective implementation and improved benefits (Dahlgaard and Dahlgaard-Park, 2006).

Table 2.2
Six Sigma Critical Success Factors and key references

Critical Success Factors	Harry & Schroeder 2000	Henderson and Evans 2000	Goldstein 2001	Pande et al. 2002	Antony and Banuelas 2002	Goh 2003	Pyzdek 2003	Breyfogle 2003	Brady and Allen 2006	Kwak and Anbari 2006	Zu et al. 2008	Schroeder et al. 2008	Aboelmaged 2010
Management commitment and support	X	X	X	X	X	X	X	X	X	X	X	X	X
Six Sigma training	X	X	X	X	X	X	X	X	X	X			X
Selection and prioritization of projects	X		X	X	X		X	X	X	X		X	X
Organizational infrastructure and resources	X	X		X	X		X	X	X		X		X
Culture	X	X		X	X		X	X	X	X	X	X	X
Belt system/Improvement specialist	X	X	X	X	X	X	X	X	X	X	X	X	X
Structured approach & Project review		X	X	X	X	X	X	X			X	X	
Customer focus		X		X	X	X	X	X			X	X	X
Understanding Tools and techniques	X	X		X	X	X	X		X				X
Link to compensation		X	X	X	X	X	X	X					
Early communication to employees		X	X	X			X	X					X
Linking Six Sigma to Business strategy				X	X		X		X				X
Financial accountability					X	X	X	X		X			
Linking Six Sigma to suppliers					X				X		X		X
Six Sigma focus on Metrics	X			X		X	X	X			X	X	
Linking Six Sigma to supply chain			X	X			X						
Linking Six Sigma to HRM					X			X					X
Data based decision making	X			X			X						X
Project management skills					X								X

Table 2.3 Key Six Sigma Critical Success Factors (CSF) identified in the literature with key references

CSF	Description	Key characteristics/attributes	Key references
Leadership and management support	The ability of management to establish, practice and lead a long-term vision for the organization, driven by changing customer requirements. Acceptance of quality responsibility and Six Sigma deployment by top management. Adhering to a whole philosophy rather than just the usage of tools and techniques.	Create urgency, communicate across the organization, create a structure to support and create an organizational environment and culture supporting Six Sigma implementation. It also includes leadership efforts towards the simultaneous creation of a cooperative and the learning organization to facilitate the implementation.	Antony et al. (2002, 2007, 2008); Schroeder et al., (2008); Linderman et al., (2003, 2010); Zu et al. (2007); Pande et al. (2000); Snee and Hoerl (2003); Henderson and Evans (2000); Cho et al. (2011); Yang et al. (2008);
Customer focus	The degree to which an organization's customers continually perceive that their needs are being met or exceeded by the organization's products and service.	Customers' needs and expectations are critically assessed, and actions are taken to satisfy them. Improvement projects are linked to customer requirements. Projects are undertaken to improve the process that improves the quality of the products and service.	Zu et al. (2008); Pande et al. (2000); Harry and Schroeder (2000); Bendell (2006); Zimmerman and Weiss (2005); Schroeder et al., 2008; Antony and Banuelas (2002); Henderson and Evans (2000); Cho et al. 82011); Manville et al. (2012); Yang et al. (2008).
Strategic project selection and prioritization	The formal mechanism to select and prioritize projects based on their link to the business strategy.	Organizations have the formal project selections and prioritization process. Projects are selected based on benefits, feasibility, and organizational impact.	Pande et al. (2000); Harry and Schroeder (2000); Snee and Hoerl (2003); Kumar et al. (2009); Zimmerman and Weiss (2005); Antony (2004); Goldstein (2001); Antony and Banuelas (2002); Schroeder et al. (2008); Goldstein (2001); Cho et al. (2011); Manville et al. (2012); Yang et al. (2008).

CSF	Description	Key characteristics/attributes	Key references
Focus on benefits and metrics	The organization emphasizes the usage of metrics to measure, track and control various process performances including financial benefits.	Critical to Quality (CTQ) characteristics are identified; baseline performances are measured, and process improvement goals are fixed for projects. Metrics such as Defect per Million Opportunity (DPMO), Sigma level, Cost of Poor Quality (COPQ) Rolled throughput Yield (RTY) are some of the performance metrics used in Six Sigma organizations. The Financial benefit for each project is estimated at the initiation of the project and verified at the end of the completion of each project.	Antony and Benuleas (2002); Pande et al. (2000);Linderman et al. (2003); Zu et al. (2008); Schroeder et al. (2008); Harry and Schroeder (2000); Kumar et al. (2009).
HRM policy, training, and communication	HRM policy to promote desired behaviour and results. Communication strategy to support company-wide adoption of Six Sigma. Rigorous training on methods and tools and adoption across the organization.	Linking contribution toward Six Sigma to reward and recognition. Promotes desired behaviour and result through recognition and compensation. Tackle resistance to change through increased and sustained communication, motivation and education. Early communication about adoption and extensive communication of success stories and lessons learned that can help projects that are in the pipeline.	Antony and Benuleas (2002); Pande et al. (2000);Linderman et al. (2003); Zu et al. (2008); Zu and Fredendall (2009); Hendricks and Kelbaugh, 1998; Chakravorty, 2009; Schroeder et al. (2008); Harry and Schroeder (2000); Kumar et al. (2009); Cho et al. (2011); Manville et al. (2012); Henderson and Evans (2000); Yang et al. (2008).

CSF	Description	Key characteristics/attributes	Key references
Culture	Change in attitude of employees toward Continuous improvement.	Employees at all levels need to be motivated to accept responsibility for the quality. Organization to have leadership/change agents, open communication and risk taking as enablers for the cultural shift and employee engagement toward continuous improvement.	Schon (2006); Davison and Al-Shaghana (2007); Zu et al. (2009); Prajogo and McDermott (2005); Pande et al. (2000); Antony and Banuelas (2002); Harry and Schroeder (2000); Kwak and Anbari (2006); Yang et al. (2008).
Project tracking and review systems, including IT support	Information support to systematically record and track the results of the repeated cycles of knowledge creation on a timely fashion. Periodic project reviews and tracking system.	Creation of information systems for data collection, online process controls, maintaining databases of projects on a real time basis. The information is available, laterally across the organization for real-time access to track, monitor and support project execution.	Anand et al., 2009; Jayaraman et al (2010, 2012); Brun (2011); Cho et al. (2011); Handeson and Evans (2000); Goldstein (2001); Antony and Banuelas (2002); Yang et al. (2008).

CSF	Description	Key characteristics/attributes	Key references
Structured methodology (DMAIC or its variants)	A standardized procedure or steps for problem solving (projects) with prescribed tools and techniques at each step, and following a systematic project management approach.	There is an emphasis on following a standard procedure in planning and conducting improvement project (DMAIC or its variants). Team use tools and techniques as prescribed in each phase of the method. At the end of each phase, review takes place to track and monitor the progress of the project.	Zu et al., 2008; Choo et al., 2007; Linderman et al., 2010; Lee-Mortimer, 2006; Kumar et al., 2008; Pande et al., 2000); Henderson and Evans (2000); Zu et al. (2008); Schroeder et al. (2008); Linderman et al. 82010); Antony and Benuelas (2002); Manville et al. (2012).
Six Sigma role structure	Specific infrastructure to introduce and implement Six Sigma, sustain and maintain to promote Six Sigma continuously throughout the organization. Creation of specialist to assume the role of change agents.	The organization uses improvement specialists having undergone rigorous training and attained skills in Six Sigma methods and tools. These specialists are assigned to specific leadership roles and responsibilities to carry out improvement projects. Others in the organizations are also trained with various skills depending on the level and roles they assume such as deployment champion, project sponsor and project team members.	Pande et al. (2000); Snee and Hoerl (2003); Kumar et al. (2009); Antony (2004); Goldstein (2001); Henderson and Evans (2000); Harry and Schroeder (2000); Zu et al. (2008); Schroeder et al. (2008); Linderman et al. (2010); Goh (2002); Anand et al. (2019).

Second school of thoughts asserts that Six Sigma is a modified form of TQM. It uses only a new deployment approach and structure, and it offers additional practices and complements traditional QM practices to improve quality and business performance (Kwak and Anbari, 2006; Schroeder at al., 2008; Zu et al., 2008; McAdam et al., 2005; Linderman et al., 2003).

2.5.1.3 Six Sigma and management theories

There is a lack of development and integration of theory and practice of Six Sigma in the literature (Llorens-Montes and Molina, 2006; de Koning and de Mast, 2006; Nonthaleerak and Henry, 2008; McAdam and Hazlett, 2010). Responding to this call, there is an emerging stream of research that focuses theoretical understanding of the Six Sigma phenomenon. Research in this stream aims to improve one's understanding of the Six Sigma phenomenon through the lenses of established management theories from other management disciplines such as strategy, organizational behaviour, learning, and knowledge Management. Table 2.4 summarizes the representative studies that use various theoretical perspectives to explain Six Sigma phenomenon, findings, contributions and shortcomings. The research outcome from this stream helps practitioners understand the antecedents and consequences of various influencing factors on organizational performance. As the table reveals, each one of them focuses on a specific aspect or dimension of Six Sigma.

McAdam and Lafferty (2004) examine how Six Sigma affects an organization and its employees at various levels in a high-tech organization and suggest that although Six Sigma is rooted in the mechanistic perspective, there is an increasing dynamic to that of a broader, more organic and strategic approach. They conclude that ‘‘Six Sigma has some way to go before it is fully accepted as a broad change philosophy, applicable across a range of organizational types’’ (McAdam and Lafferty, 2004: 545-546). This view is also supported by others (Henderson and Evans, 2000; Goh, 2002; Kuei and Madu, 2003; Schroeder et al., 2008). Schroeder et al. (2008), for example, claim that Six Sigma helps an organization become more ambidextrous by providing a switching structure (improvement specialists) that allows the organization to act more organically in coming up with new improvement ideas and operate more mechanistically when implementing them (Schroeder et al., 2008). Henderson and Evans (2000) suggest that operational Six Sigma can create an upward pressure for a more strategic based approach. Though there is a strong support in the literature for Six Sigma being considered as mechanistic, a growing number of papers have recently claimed that Six Sigma has indeed been a strategic change initiative (Antony et al., 2008).

Braunscheidel et al (2011), using an *institutional theory* framework, seek to explain the influencing mechanisms that motivate the adoption of six sigma in organizations. The researchers conducted case study research in 7 manufacturing organizations and investigated the influence of the following institutional isomorphic mechanisms on Six Sigma adoption.

- Coercive (pressure from other firms such as customer firm)
- Mimetic (managers mimic a successful firm)
- Normative (managers through their professional or trade association form perceptions of industry norms and expectations; develop a shared mental model of the institutional environment)

They establish that the above three mechanisms impact Six Sigma adoption. The study, however, fails to explain other possible internal requirements or reasons for adoption such as improvement culture wanted by management (Pande, 2002; Zu et al., 2010) or the climate that is so conducive that organization is willing to adopt formally Six Sigma (Harry and Schroeder, 2000; Pande et al., 2002), or the top management's willingness to adopt Six Sigma in their organizations.

Linderman et. al (2003) apply *goal theoretic perspective* to Six Sigma and suggest that a clear and challenging goal in the Six Sigma organization lead to more team member effort, persistence and focus on activities that help accomplish improvement activities. Further, the authors empirically established that challenging goal enhances project performance and that the degree to which teams adhere to the use of tools and methods (DMAIC) positively moderates the effect of challenging goals for project performance (Linderman et.al., 2006) Extending this, Gutierrez et.al (2009) argue and establish that challenging goals help establish better orientation among team members toward a shared vision that in turn helps achieve project success. Although goal theoretic perspective explains the motivational aspect of project teams, it does not adequately explain the dynamics involved in adopting and legitimizing Six Sigma within organizations (McAdam et al., 2011). While institutional theory explains the motivational aspects of companywide adoption of Six Sigma, Goal theoretic perspective explains the motivational aspects within the project team that support the adoption.

Building on the premise that reward/recognition is considered as one of the most powerful forms of Six Sigma motivation and such companies as Motorola and GE have relied heavily upon its power, Buch and Tolentino (2006) using the *theory of work motivation* investigated the effect of reward on employee motivation to participate in Six Sigma projects. Although their study could explain the positive relationship between Six Sigma-based reward systems and employee motivation to participate in Six Sigma efforts, the study does not explain how non participants in projects are motivated to engage in Six Sigma adoption and projects that is required for sustainability of Six Sigma adoption. Further, the study does not address the knowledge acquisition aspects of Six Sigma, which is central to quality improvement, especially Six Sigma program (Anand et al., 2009; Arumugam et al., 2013; Linderman et al., 2003; Llorens-Montes and Molina, 2006; Schroeder et al., 2008; McAdam and Hazlet, 2010) and its synergies with other change management initiatives. Llorens-Montes and Molina (2006), taking an economic perspective, propose that specialist structure (Belts and champions) reflect the *agency theory* and that the specialists are seen as agents to cascade down the Six Sigma program throughout the organization thus helping to achieving organizational goals as agents. In a similar vein, Gowen et al. (2008) sing a *resource-based view* (RBV) and dynamic capability analysis, explore the Six Sigma competencies for sustainable competitive advantage. These perspectives fail to support the other contexts of adoption such as motivation and behavioral aspects of teams that are required for successful adoption.

Anand et.al (2009) proposed and verified through an empirical data from 5 organizations that the infrastructure of Six Sigma such as a standardized improvement process (DMAIC), change culture, participative specialist structure, training and information technology support enable Six Sigma to be a *dynamic capability*. Dynamic capability is defined as ‘‘a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness’’ (Zollo and Winter, 2002, p. 340). Six Sigma involves organizational learning that makes changes and improvement in operating routines, and thus dynamic capability. Their study provides an empirical evidence to dynamic capability perspective of Six Sigma. Similarly, Gowen and Tallen (2005) through a survey research at 66 organizations empirically established that technical (project selection and project review and sharing best practice) and human aspects of Six Sigma deployment (specialists selection, training and recognition) provide dynamic capability and generate competitive advantage. Further research is needed to extend these findings to investigate the impact of other aspects of the adoption on dynamic capability.

While these theories provide insights at a piecemeal level (goal theory, institutional theory, and agency theory, and dynamic capability), they all fail to provide a comprehensive guidance for understanding the process of Six Sigma and its multilevel characteristics, including antecedents, processes, and consequences. Scholars are of the view that there is no coherent and overarching body of theory to underpin or drive Six Sigma developments in practice (Schroeder et al. , 2008; Nonthaleerak and Henry, 2008; McAdam et al., 2005; Llorens-Montes and Molina, 2006). The interaction of multiple theories relative to single theories, integration of managerial actions, and involvement of people in the organizations (interconnecting sociotechnical systems, motivations, technical, social identity, social exchange, and social capital), along with internal social behaviors, and external influences such as customers and environmental factors may explain the Six Sigma from a proper perspective.

In this aspect, the *present research makes a beginning in applying multiple theories* to explain Six Sigma phenomenon. Study 3 of this research (explained in chapter 3 and 7) combines knowledge management, *goal theory* of motivational research discipline, and *Sociotechnical systems theory* of organizational development research discipline to explain project success.

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Table 2.4 Theories borrowed from other disciplines to explain Six Sigma Phenomenon

Theory and authors	Level of analysis/ research method	Focus and findings	Theoretical contributions and remarks
Institutional theory Braunscheidel et al., 2011	Organization. Case study. Seven manufacturing organizations	Investigate whether Institutional theory can best explain the adoption of Six Sigma. The three isomorphic change mechanisms (coercive, mimetic and normative) and climate for implementation and innovation-value fit affect implementation. Six Sigma impacted customer satisfaction and performance in case organizations.	The study identifies three influencing mechanisms that impact Six Sigma adoption. The theory fails to explain other possible internal requirements or reasons for adoption such as improvement culture wanted by management or the climate that is so conducive that organization is willing to adopt formally Six Sigma.
Resource-Based View and Dynamic Capability Model Gowen and Tallen, 2005	Organization. Survey research, 66 organizations (manufacturing and service).	Dynamic capability view of Six Sigma provides a framework for understanding both technical (project selection, review, and sharing best practice) and human aspects of Six Sigma factors (Specialist selection, training, and recognition) provide Dynamic capability and generate Competitive Advantage.	The RBV and dynamic capability views offer a logic and rationale behind Six Sigma adoption by organizations. The research, however, fails to consider the effects of learning and knowledge creation that takes place in teams that can enhance dynamic capability.
Dynamic capability view Anand et al., 2009	Conceptual with case study evidence from 5 companies	Infrastructure elements of Six Sigma such as balanced innovation and improvement, standardized improvement process (method), a constant change culture, parallel participation structure, information technology support and training enable Six Sigma to be a Dynamic capability.	Provides preliminary empirical evidence of dynamic capability perspective and its underlying theory of organizational learning for continuous improvement such as Six Sigma.
Goal theory Linderman et al. 2003, 2006	Project team. One case organization. 951 members (Team leaders and members) from 206 projects.	The study incorporates the theory from organizational behaviour in studying the operations management phenomenon. The study investigates the impact of goals in project teams.	Explains motivation in project teams, and established that setting challenging goals can be effective when teams adhere to Six Sigma tools and method. The study informs that social aspects of goal (motivation) and technical aspects of problem solving jointly impact performance. The perspective does not explain the motivation in adoption by the organization at organization (macro) level.

Table 2.4 (contd..)

Theory and authors	**Level of analysis/ research method**	**Focus and findings**	**Theoretical contributions and remarks**
Mechanistic and organic theories McAdam and Lafferty, 2004 McAdam et al., 2005	Organization. Literature review and multi-level case study (management, engineers, and technicians)	To explore Six Sigma phenomenon from both process and people perspectives. Empowerment, communication, reward, and HR intervention in the existing culture are some of the critical factors for successful deployment.	Organic and mechanistic approaches are used to explain the dichotomies and complexities within Six Sigma (problem solving versus change management program). How people in the organizations at various hierarchical levels organize themselves to the overall implementation of Six Sigma is not explained.
Agency theory Llorens-Montes and Molina, 2006	Conceptual research	To explore Six Sigma in economic perspective, using Agency theory. Six Sigma belt systems reflect agency theory, where specialists are seen as agents to cascade the Six Sigma change initiative down throughout the organization on behalf of the top management.	The theory could explain the development of Belt systems and its activities. It fails to explain the motivational aspects of deployment and projects and other behavioural aspects of Six Sigma.
VIE theory of work motivation Buch and Tolentino, 2006	Survey research with 215 employees	The perception of rewards (intrinsic, extrinsic, social and organizational) varies depending upon the level of participation, such as GB, BB, and non-participation. The participants perceive that their involvement leads to valued outcomes for themselves and the organization.	Theory of work motivation is used to study the effects of rewards on employees ' motivation in participating in Six Sigma projects & reward systems. Limited application to a parallel learning structure and the reward systems used to support it.

2.5.1.4 Six Sigma and Performance

The last stream of research focuses on the effect of Six Sigma on organizational performance. It includes empirical studies that use perceptual data collected through surveys (Lee and Choi, 2006; Choi et al., 2012; Van Iwaarden, et al. 2008; Gowen et al., 2008; Wu and Lin, 2009; Antony et al., 2005, 2007a; Braunscheidel et al. 2011; Zu et al., 2008; Gutie´rrez et al., 2009; Jayaraman et al., 2012) and secondary financial data (Goh et al., 2003; Foster, 2007; Swink and Jacobs, 2012; Shafers and Moeller, 2012). In this stream, scholars investigate how effective Six Sigma is on improving organizational performance and effectiveness. Some of the articles examine the effects of one or more CSFs on organizational performance.

Table.2.5 summarizes some of the recent empirical studies on the impact of Six Sigma on performance, showing research models and measures used in the respective studies. Most earlier studies, including case studies have shown Six Sigma as a methodology to improve the cost of poor quality (CoPQ) of firms through process and quality improvement (Hoerl, 1998). Recent research, however, seeks to claim that Six Sigma in fact enhances delivery of products and improves profitability (Van Iwaarden et al., 2008; Antony et al., 2005; Braunsheidel et al. 2011; Jayaraman et al., 2012), enhances customer satisfaction (Chen et al., 2005; Desai, 2006; Kuei and Madu, 2003; Kumar et al., 2007; Freiesleben, 2006; Breinsheidel et al. 2011), increases employee satisfactions (Schon et al., 2010), and creates Competitive Advantage (Gowen et al., 2008; Lee and Choi, 2006; Choi et al., 2012; Freiesleben, 2007). A transnational study (covering the United Kingdom, United States and the Netherlands) by Van Iwaarden, et al. (2008) finds that financial motivation is the major reasons for implementing Six Sigma followed by customer service and the development of a continuous improvement culture in the organization

2.5.1.5 Project success

By considering project success to be the primary factor for the successful deployment of Six Sigma, many recent studies have focused on factors that have a potential impact on project success. Nair et al. (2011) through an action research investigation of 10 Six Sigma projects conducted over multiple years, examine the effects of organizational factors, project elements, and project-level contextual factors. The researchers identify factors such as leadership engagement, strategic project selection and psychological safety, project complexity, and uncertainty as affecting project success. The findings suggest that project-level factors may be more important determinants of project success.

Table 2.5

Selected studies on Six Sigma and performance

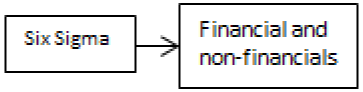
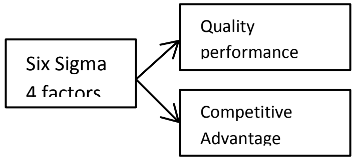
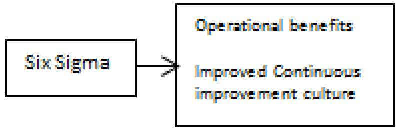
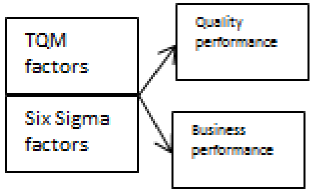
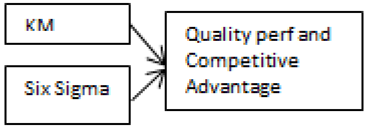
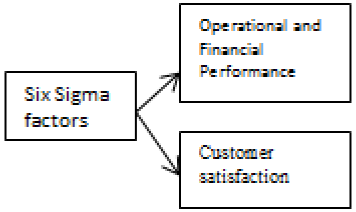
Authors & model	Framework	Method	Predictors	Outcome indicators	Key findings
Antony et al. 2005 	The effects of Six Sigma on Performance in small and medium sized UK manufacturing enterprises	60 manufacturing SMEs in the UK Survey method	Six Sigma implementation	Non-financials: Reduction in process variability, cycle time reduction, productivity increase, reduction in customer complaints, Financials: Reduction in operational cost, COPQ, Improved sales	The results based on primarily on descriptive statistics show evidence that Six Sigma enhances operational and business performance.
Lee and Choi 2006 	The effect of four Six Sigma management factors on process and quality improvement	Companies of one single corporate. 161 survey questionnaires SEM analaysis	Information system, communication, Education/training, Policy/System	Process Innovation Quality, Corporate competitiveness	All four Six Sigma management factors have a positive impact on process innovation. Information system and Policy/System has no effect on the quality.
Antony 2007 	The effects of Six Sigma on performance in UK service organizations	25 service organizations in the UK. Survey method	Six Sigma implementation	Customer satisfaction, defect rate, variability of processes, culture, cycle time, operational cost, market share	Respondents perceived that Six Sigma implementation helped to improve performance, both financial and non-financial.

Table 2.5 (contd...)
Selected studies non Six Sigma and performance

Authors & model	**Framework**	**Method**	**Predictors**	**Outcome indicators**	**Key findings**
Zu et al., 2008 	The effect of traditional quality processes and 3 Six Sigma processes on performance	226 US manufacturing plants Survey method	*Traditional QM factors:* Top management support, customer relationship, Supplier relationship, workforce management, quality information, product/process management. *Six Sigma factors:* Role structure, structured procedures, and focus on metrics.	Quality performance, Business performance (sales, market share, unit cost of manufacture, operating income, profit, and ROA)	The three Six Sigma practices are distinct practices, and they complement the traditional quality management practices. Together they impact business performance
Gowen et al., 2008 	Impact of Six Sigma along with knowledge management on quality and sustainable CA	112 Hospitals from USA, Hierarchical regression	Six Sigma initiative and knowledge management practices	Quality improvement, Customer satisfaction, error reduction, cost savings, value added, rareness, costly to imitate, non-sustainability.	Six Sigma enhances quality results and CA. Knowledge management support for SS greatly improves the effectiveness of SS program.
Braunscheidel et al., 2011 	Effect of three influencing mechanisms (coercive, mimetic and normative) on adoption and implementation and the Impact of Six Sigma on performance and customer satisfaction	7 manufacturing organizations. Multiple case study	Implementation effectiveness of Six Sigma	Operational and Financial performance	Implementation results in operational, financial performance and Customer satisfaction

Recent empirical studies find project-level factors such as structured methods and team psychological safety (Choo et al., 2007b), challenging and stretched goal (Linderman et al., 2006; Choo, 2011), Black Belt coaching (Hagen 2010) to affect project performance positively. The study of Easton and Rosensweig's (2012) indicates that project leader experience has a significant effect on project performance, whereas team familiarity in the context of well-developed structured problem-solving methods have no importance.

2.5.1.6 Learning and knowledge creation in project teams

Increasingly, recent studies have focused on the antecedents of project performance and found the mediating role of learning and knowledge in teams. Linderman et al. (2010) suggest that the interaction between the social support and technical support enables process improvement technique to create knowledge and solve problems. The formal problem solving approach (DMAIC or its variants) used in Six Sigma project facilitates rational decision making and improves organizational routines and processes (Anand et al., 2010; Linderman et al., 2010). Scholars have argued that the intentional improvements of processes and routines create organizational knowledge (Nelson and Winter, 1982; Argote, 1999). As people carry out more and more projects and master the tools and techniques of Six Sigma, they stand to gain experience in scientific problem solving. In the context of Six Sigma, it is, therefore, argued that six sigma enhances team and organizational learning. Thus, the deployment of Six Sigma provides a conducive environment where deliberate learning in induced in improvement teams which improves members' ways of using knowledge (Arumugam, 2011; Llorens-Monntes and Molina, 2006; Wiklund and Wiklund, 2002; Pande et al., 2000; Linderman et al., 2010). In particular, specialists who lead projects facilitate team members to attain skills in problem solving and to gain increased process knowledge (Wiklund and Wiklund, 2002; Linderman et al., 2006, 2010; Choo et al., 2007; Anand et al., 2009; Llorens and Molina, 2006, Savolainen and Haikonen, 2007).

Building on these notions, a growing body of research is exploring how learning and knowledge creation is facilitated in Six Sigma. More specifically, scholars focus on the various project-level and organizational antecedents that affect learning in project teams and the effectiveness of the organization and business performance. Table 2.6 displays representations of the empirical studies in this stream of research.

Six Sigma project teams are temporary, formed to improve a specific process, and have a short project duration (generally three to nine months) (Antony, 2007a; Pande et al., 2000; Pyzdek, 2003). Except for the project leader, members contribute only a fraction of their work time. Therefore, social ties are not as close as in other project teams (Anand et al., 2010). Learning and knowledge transfer, therefore, is through specific practices used by the Six Sigma project team during the project such as DMAIC method, and project leaders' knowledge-gathering behaviour in gathering individual knowledge and synthesizing into team-level knowledge to solve problems (Arumugam, 2011; Anand et al., 2010). The challenging improvement goals (stretch strategy) for projects motivate organizational members to engage in intentional learning activities that create knowledge and make improvements (Locke and Latham, 1990; Linderman et al., 2003, 2006; Choo, 2011).

In the Six Sigma context, learning is induced by a series of deliberate activities of the Six Sigma program. Members of the project team are given extensive training in problem-solving approaches. In Six Sigma project, a cross-functional team brings in, different knowledge domains and facilitates the flow of information and knowledge across functional boundaries (Gupta and Govindarajan, 2000), to d develops team-level knowledge. Team members learn from each other and knowledge is shared widely among the members through various techniques adopted in DMAIC phases.

Learning behaviours of the Six Sigma project team include discussions within and outside the team (Pande et al., 2000; Pyzdek, 2003; Arumugam, 2011; Anand et al., 2010), seeking information and knowledge from external experts in related fields (Arumugam, 2013), critical observation of the process (Arumugam et al., 2012), and seeking information and knowledge from customers and suppliers about the process (Nair et al., 2011; Chakravorty, 2009). Interaction with outside people creates an interpretation of knowledge through common cognitive schemas and frameworks (Weick, 1979), metaphor and analogy (Nonaka and Takeuchi, 1995), and stories and narratives (Brown and Duguid, 1991).

Table 2.6
Six Sigma and Learning and knowledge creation

Authors	Research method	Predictors	Dependent variables	Mediators	Key findings
Choo et al., 2007b	206 project teams from one single organization. 951 responses (project leaders and members).	Method and Psychological safety	Project performance	Learning, Knowledge	Method mechanism influences learning behaviours, and psychological mechanism affects knowledge. Learning behaviour affects project performance through knowledge.
Wu and Lin , 2009	Case study	Six Sigma program processes: voice of the customer, structured method, management involvement and commitment, change management, infrastructure management, process management and measurement	n/a	Knowledge creation	Six Sigma program facilitates the knowledge creation process through socialization, externalization, combination and internalization (SECI) and by providing an environment and conditions ('ba').
Anand et al., 2010	Survey research 98 project teams from 5 organizations	n/a	Performance	Technically oriented (explicit) knowledge Socially oriented (tacit) knowledge	Two different knowledge transfer explains the differential project success
Gutiérrez et al., 2011	Survey research 58 firms	Teamwork and Process management	Learning orientation	Absorptive capacity	Teamwork and process management independently impact absorptive capacity, which in turn impact learning orientation of the employees.
Choo, 2011	206 project teams from one single organization. 951 responses (project leaders and members).	The problem driven gap and performance driven gap	Knowledge created	Sense of challenge	A sense of challenge creates knowledge in project teams.

Table 2.6
(contd...)
Six Sigma and Learning and knowledge creation

Authors	**Research method**	**Predictors**	**Dependent variables**	**Mediators**	**Key findings**
Malik and Blummenfeld, 2012	Case study research. Semi-structured interviews, documents	Quality management capabilities: Commitment to quality and information sharing, Continuous improvement and Teamwork	Organizational learning capability (Commitment to learning, Open-mindedness, and shared vision)	n/a	Different levels of team working, CI and commitment to quality and information sharing variously influence the development of organizational learning.
Sony and Naik, 2012	Survey research 495 sample firms.	Six Sigma role structure, structured method and focus on metrics. Organization type as a moderator.	Innovation, performance	Organizational learning capability (Commitment to learning, Open-mindedness, and shared vision)	Six Sigma impacts innovation mediated through organizational learning. Role structure influences all three constructs of learning. Structured method impacts only commitment to learning and no relationship with shared vision and open mindedness. Organization type does not have any moderating effect on organizational learning.

The DMAIC approach is an enabling mechanism in organizational learning that fosters learning among members at a faster rate than they would otherwise. The learning and knowledge created are also transferred to other areas where the organization has similar processes. Team members also carry with them their new skills and knowledge to other areas where they are assigned to either new projects or a new job (Hoerl, 2001).

The review shows that factors, such as management involvement and commitment, structured method, training, resources, role structure, psychological safety, teamwork, challenging goal, team leader, and teamwork influence learning in project teams. Overall, the deployment of Six Sigma provides a positive and conducive environment where deliberate learning (Zollo and Winter, 2002) are induced in improvement teams which improves members' ways of using knowledge (Anand et al., 2009; Arumugam et al., 2013; Lloréns and Molina, 2006; Wiklund and Wiklund, 2002; Pande et al., 2000; Linderman et al., 2010; Gowen III et al., 2008; Llorens and Molina, 2006).

2.5.1.7 Financial performance

Taking on the notion that Six Sigma focuses on financial outcomes in each project, scholars looked at the financial implications of Six Sigma success. Notable among the studies in this stream that use secondary financial data for analysis are Goh et al., (2003), Foster, (2007), Pulakanam (2012), Swink and Jacobs (2012) and Shafers and Moeller (2012) who adopt event study methods to assess the performance effects of Six Sigma deployment. These studies investigate the financial performance of the sample organizations before and after the Six Sigma adoption and compare the performance of matching control firms.

Goh et al (2003) for example, examine the impact of Six Sigma announcement of the stock price performance of 20 firms, but found no significant evidence for the impact of Six Sigma in stock returns on announcement day. Shafer and Moeller (2012) studied the financial performance for 10-year period (3 years prior to adoption, adoption year and 6 years post adoption) of 84 firms which have adopted Six Sigma in 2004 or earlier. The findings reveal that Six Sigma firms outperform their control counterparts in year three on in many of the financial performance metrics. They find that the performance is primarily driven through the efficiency through which employees are deployed, which is consistent with the findings of Swink and Jacobs (2012) who compared the performance of 214 Six Sigma-adopting firms with matching control firms for a 6-year period (one year before adoption to 4 years after). They argue that Six Sigma creates new learning and adaptation capabilities within the firm and that by its very nature of deployment, Six Sigma promotes a culture of problem solving that fosters continuous improvement (CI) and sustains a competitive advantage.

Swink and Jacobs (2012) find no significant difference between manufacturing and service firms and they suggest that labor-intensive repeatable processes offer the greatest opportunities for Six Sigma adoption. Another interesting finding that needs further research is quality-maturity (such as ISO 9000 implementation prior to Six Sigma adoption) that appears to benefit less from Six Sigma adoption. This finding differs from that of previous research of Shah et al. (2008) and Van Iwaarden, et al. (2008). Further, the results indicate that prior financial performance has a significant effect only in the case of service industry, but not in manufacturing firms. They find that both profitable firms (have enough resources to invest) and loss-making firms (have an urgency to implement changes for improvement) appear to gain more from Six Sigma adoption. This is also consistent with the finding of Shafer and Moeller (2012), which has shown that the decline in performance continuously for a period of more than 2 years is a motivation for adoption in their sample organizations. The study by Pulakanam (2012) for the first time compares the investment made in Six Sigma with the benefits brought out by its adoption and points out that the benefits outweigh the investment made toward deployment. Overall, the research in this stream has found increasing evidence that Six Sigma indeed impacts financial performance.

2.5.2 Synthesis

The section starts with a brief review of the findings, followed by an overview of the trends observed and gaps identified. Based on these results, a multilevel framework will be developed.

Overall findings from the research stream on CSFs and implementation scheme reveal that CSFs are common or at least the top ten CSFs across sectors such as manufacturing and service (Antony et al., 2007; Chakrabarty and Taan, 2007), across sizes such as small and big (Timans et al., 2012; Antony et al., 2008; Kumar, 2007; Cho et al., 2011) and across countries (Van Iwaarden et al., 2008). The relative importance of these CSFs varies as viewed by managerial hierarchies such as senior managers to middle managers (Manville et al., 2012); varies from company types such as manufacturing and service (Cho et al., 2011); varies depending upon the stages of implementation such as introduction, expansion and stabilization (Cho et al., 2011; Firka, 2010); and finally it also varies from countries to countries (Van Iwaarden et al., 2008; Cho et al., 2011; Sunil and Anuradha, 2012). Top management commitment, for example, is most critical during the initial period of adoption, but during the maintenance period, project selection becomes the most important factor.

The studies that use secondary financial data for investigation include only larger organizations due to data availability in public domains (Shafer and Moeller, 2012; Swink and Jacobs, 2012). Studies that use perceptual data from SMEs have shown that Six Sigma impacts business performance. The findings show that Six Sigma is capable of delivering financial benefits, and the benefits outweigh the investment made.

The majority of the studies which investigate the performance effects of Six Sigma considers Six Sigma as a single dimensional process (exception Zu et al. 2008 and Lee & Choi, 2006), missing to explore the effects of various individual CSFs of Six Sigma on performance. The studies that use project as the unit of analysis, investigate the impact of project level factors such as method, resources provided to the team, challenging goals, team level social factors such as cohesion, learning orientation, and psychological safety on performance. These studies also establish that project success is mediated by learning and knowledge creation in teams.

To a limited extent, scholars succeed in using various management and behavioural theories to explain one or more specific features on Six Sigma. Through Resource-based View and institutional theory, Six Sigma is beginning to be established as a business improvement strategy.

The streams of research indeed help enhance one’s knowledge of Six Sigma, its definition, theoretical underpinnings, and differences from other quality management initiative such as TQM. The review suggests that the impact of Six Sigma adoption is more a function of the overall structural and cultural aspects, and less about the focused application of statistical tools that are more frequently applied in the manufacturing sector (Swink and Jacobs, 2012; Antony et al., 2008).

Despite the usefulness of the individual studies and their findings, there remains unanswered a more fundamental theoretical base in understanding the Six Sigma phenomenon. Based on the observations and the evidence of studies cited earlier, there is sufficient basis to conclude the following.

- The success of Six Sigma implementation depends upon project-by-project focus. Although theoretically one can argue that projects successes collectively lead to organizational performance, the examined empirical studies fail to capture the simultaneous measurement of project success and organizational performance to establish the linkage between project performance and Six Sigma implementation success.
- As Six Sigma implementation and the consequent operational and business performance are influenced mostly by project success, the ways in which Six Sigma brings out business performance improvement, therefore, are different from those of other quality initiatives.
- The empirical evidence shows that project performance is mediated by learning and knowledge creation in teams.
- The review did not find a strong unifying theory explaining Six Sigma phenomenon that covers all the dimensions that could operate across levels (macro and micro). A multi-level analysis by investigating the effects of organizational CSFs on project level factors and in turn on project performance will throw more insights into the Six Sigma phenomenon.

In order to address the above gaps, the researcher proposes a comprehensive research framework by integrating the findings of the four research streams.

2.5.3 Framework

Based on the findings, the researcher proposes a multilevel framework linking managerial actions at the organizational level that impact project execution at the team level to produce outcome at the project level, leading to a performance at the organizational level. The proposed framework (Figure 2.4) combines organizational factors, project level factors, contextual factors and performance as found from the review. The various elements of the framework are connected based on the evidence collected from the studies examined. Organizational factors refer to those elements governed by the actions of managerial personnel outside the project team. Project-level factors are those factors that are characteristics of projects and are mostly governed or undertaken by the project team, both team leaders, and members (i.e., actions within the project).

The framework includes both project performance and business performance. Project Management literature has identified various aspects of project performance as benchmarks for measuring the success or failure of a project. Project performance is multi-dimensional and Shenhar et al. (2002) arrange project performance into three dimensions: (1) meeting project goals (technical and operational performance of the final project outcome and meeting the schedule and budget goal); (2) benefit and impact of the project outcome on the customer; and (3) benefit to the organization (commercial success, the extent to which the project creates new opportunities and financial benefits). Contextual factors are either at organizational level or project level and are situational opportunities and constraints that affect organizational behaviour and functional relationships between variables (Johns, 2006). The individual, the interpersonal relationships, institutional setting and the wider infrastructural systems are the major contextual factors in any intervention (Pawson and Tilley, 1997). Business performance refers to the financial and commercial performance of the organization. Operational performance refers to all non-financial improvement metrics.

The model starts with an awareness of the importance of quality that leads to the deployment of Six Sigma. More than 50% of the papers on CSF mention leadership commitment, involvement and support as one of the most important success factors. The effectiveness of the intervention depends upon the culture prevailing in the organization and the *cultural readiness* developed by the management through various measures such as the creation and deployment of vision and mission, and putting in place a robust communication strategy to cascade down the strategy. Appropriate Six Sigma infrastructure development and human resources development strategy will create a cultural atmosphere conducive to successful adoption (Antony and Banuelas, 2002; Henderson and Evans, 2000; Llorens-Montes and Molina, 2006; Zu and Fredendall, 2009). The Human Resources Management policies facilitate the development of competencies that are specific to Six Sigma, encourage employee involvement, develop and impact employee training, and offer recognition, which all affect project execution through a structured process (e.g., DMAIC) and, in turn, on performance (Zu and Fredendall, 2009).

An essential element of the success of Six Sigma program is its ability to link the deployment to customers. Six Sigma is uniquely driven by close understanding of customer needs and initiating projects to address customer expectations in products and service. Projects need to be selected, and prioritized based on their direct link to the business strategy and approved by the senior management team (Schroeder et al., 2008; Kumar et al., 2008). A powerful feature of Six Sigma is the creation of an infrastructure to assure that the selected and prioritized projects (Antony, 2004a; Schroeder et al., 2008; Kumar et al., 2009) are provided with the necessary resources. Overall, the top management support directly affects the implementation of Six Sigma.

The Six Sigma infrastructure includes recruitment, selection (both internal and external), training, and development of talented individuals at various levels of Belts (Master Black Belt (MBB), Black Belt (BB), Green Belt (GB), and Yellow Belt (YB). Training is also given to senior executives who take responsibilities as deployment champions. Only in Six Sigma, training programs are tailored to match specific to the management members depending upon their levels at which they participate and contribute towards the successful deployment of Six Sigma program (Coronado and Antony, 2002; Goh, 2002).

Resource for Six Sigma deployment includes information system support, documented procedure for the selection and prioritization of strategic projects, constantly assessing progress of the projects, and providing support to the people involved in projects, and reward people suitably on their successful completion of the projects (Antony & Banuelas, 2002; Chou et al., 2011; Handerson and Evans, 2000; Linderman et al., 2003, 2010; Jayaraman et al., 2012; Schroeder et al., 2008).

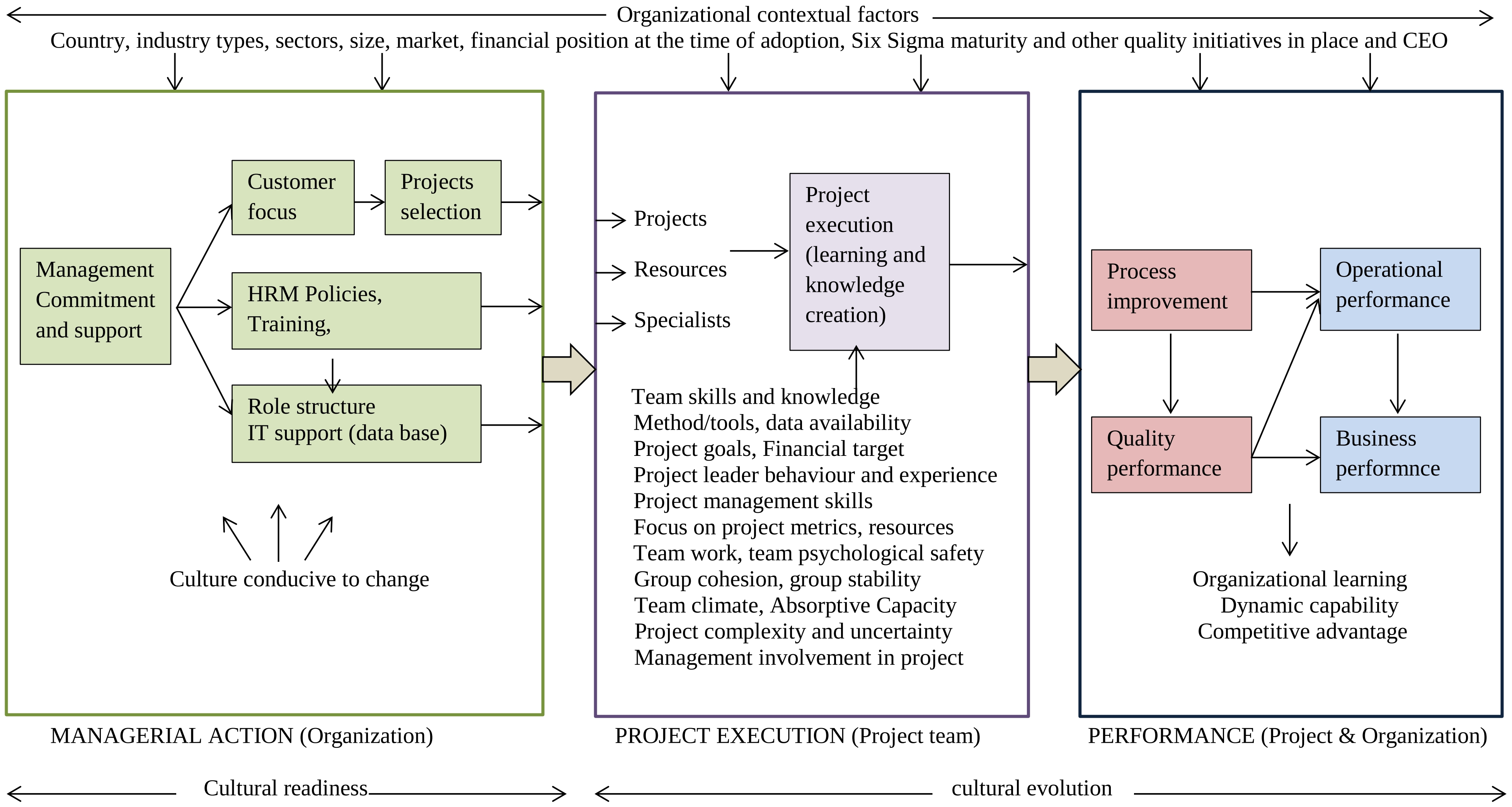


Figure 2.4 Multilevel framework

Project selection and prioritization, which are linked to an organization's strategy (Antony, 2004a; Schroeder et al., 2008), using quantitative metrics to track, monitor and control project outcome, and structured methodology all affect the organization's culture and help to produce individual and organizational outcomes through cultural sustainability and finally business performance. Individual effectiveness enhances job satisfaction, learning, and skills development and organizational outcome, such as organizational learning, improvement in processes and the resulted product quality, and operational and business performance and ultimately competitive advantage. The framework indicates (Figure 2.3) various factors identified in the literature that impact project execution and performance.

The review has identified various project level factors that affect projects. Project goals (Linderman et al., 2003, 2006; Locke and Latham, 1990, 2002), project scope (Snee and Hoerl, 2003), resources (Schon, 2006), project leader behaviour (Hagen, 2010) and experience (Easton and Rosenzweig, 2012), project team leader's style (Llorens and Molina, 2006) team's project management skills (Antony and Banuelas, 2002), team's focus on project metrics (Zu et al., 2008), matching skill and availability of the people to projects (Kumar et al., 2008), team's goal orientation (Gutierrez et a., 2009), team leader style (Kun-Shan et al., 2012), functional diversity of the team (Snee, 2004), the resources provided to the team (Nair et al., 2011), availability of specialist (Nonthaleerak and Hendry, 2008), team psychological safety (Choo t al., 2007) teamwork (Gutierrez et al., 2011) group cohesion (Gutierrez et al., 2009; Kun-Shan et al., 2012), team's empowerment (McAdam and Lafferty, 2004), communication (Rajamanoharan and Collier, 2006), learning behaviour of the team (Choo et al., 2007), Knowledge sharing and knowledge created in the team (Choo et al., 2007; Rajamanoharan and Collier, 2006), absorptive capacity (Gutierez et al., 2012) and project complexity and uncertainty (Nair et al., 2011), adhering to the method (Choo et al., 2007; Linderman et al., 2006), team's skill level in tools and method (Antony and Banuelas, 2002, Manville et al., 2012) are some of the factors affecting project performance. The majority of these factors is also found to be affected by organizational factors as noted earlier. Table 2.7 depicts the measurement model with key references for measurements of the factors.

The DMAIC methodology improves knowledge sharing, communication and learning by the people in the organization (Anand et al., 2009; Choo et al., 2007). Capabilities are subsequently embedded in experiences and practices in terms of new practices and processes that enhance dynamic capability (Teece, 2000). As the organization carries out projects after projects, the members of the organization think differently and act differently resulting in changes in their mindset. The people are expected to manage with facts and data which demands a paradigm shift and organization becomes data driven and a culture of Six Sigma thinking embeds in the organization- *cultural evolution*. As more and more projects are carried out involving more and more people in the organization, new way of doing things, new ways of collaborations both within the firm and across the firm, and new collaborative communications are adopted and evolved. Culture has an influential role on effective implementation, while the relationship between culture and Six Sigma is also well acknowledged in the reviewed literature (Antony and Banuelas, 2002; Zu, Robins and Fredendall, 2009; Cho et al., 2011; Lorens-Montes and Molina, 2006; Motwani, Kumar and Antony, 2004; Thawani, 2004).

At the end of each project, the senior management team is involved in the integration and institutionalization of the improvement achieved. Further, it helps sharing of the knowledge gained and the lessons learned throughout the organization, and achieve greater effectiveness in its deployment Six Sigma, leading to a well-defined organizational structure that facilitates leadership engagement (Schroeder et al., 2008). The next section will briefly explain how project success enhances organizational and business performance and how this is different from other QM initiatives.

2.5.3.1 Process and quality improvement

In the Six Sigma context, process improvement means increasing the current level of average performance to a new level, taking the capability of the process to a new higher sigma level (Harry and Schroeder, 2000; Pande et al., 2000). This is achieved by identifying the input characteristics that are vital for CTQs and taking actions on those input variables that lead to less process variation. Less process variation reduces waste and increases process efficiency (Andersson et al., 2006; Antony and Banuelas, 2002; Henderson and Evans, 2000; Hoerl, 1998). As the organization carries out a series of such projects, this cycle repeats. The enhanced capabilities of those processes lead to the improved quality of the products or services coming out of the processes. As a result, CoPQ is reduced, leading to increased financial gain (Handfield et al., 1998; Kaynak, 2003; Reed et al., 1996; Swink and Jacobs, 2012).

Business performance comprises both the financial and the operational performance of the firm (Venkatraman & Ramanujan, 1986). Financial performance includes sales growth, profitability (return on assets, return on sales), earnings per share and operational performance includes non-financial performance metrics such as market share, number of new product introduction, product quality, manufacturing value added, and the technological efficiency of the firm. Six Sigma impacts business performance and the impact is realised in the following three ways: (1) process efficiency and productivity increase that affect profitability, (2) improved quality of products increase customer satisfaction and in turn sales revenue; and (3) reduction of CoPQ, which is added to the bottom line (Ahire and Dreyfus, 2000; Choi and Eboch, 1998; Handfield et al., 1998).

As process variability is reduced, the reliability of the product is enhanced, which can improve firm revenue (Reed et al., 1996). Swink and Jacobs (2012) assert that Six Sigma facilitates sales growth: (1) by supporting product innovation; (2) through reputational enhancements that improve product and brand image; and (3) through process improvements that create better product quality. The high efficiency of the processes and increased productivity can improve some of the financial ratios such as return on assets (RoA), which is a measure of profitability (Handfield et al., 1998; Kaynak, 2003). Improved quality increases customer satisfaction and hence market share (Ahire & Dreyfus, 2000; Swink and Jacobs, 2012) and the firm can earn higher profits (Kaynak, 2003; Sousa and Voss, 2002), influencing the firm’s overall business performance.

Organizational contextual factors

Country, types, sectors, and size
Market condition
Financial position at the time of adoption

Six Sigma maturity, Quality maturity,
Other quality initiative in place (ISO, TQM etc.)

CEO's will
(Choi et al., 2012)

Managerial Actions	Project Execution		Organizational Performance
Commitment and support (Zu et al., 2008; Kaynak, 2003; Jayaraman et al., 2012 ; Davison and Al-Shaghana, 2007) Customer focus/support (Zu et al., 2008) Project selection/prioritization and review (Kumar et al., 2008; Jayaraman et al., 2012) HRM (Zu and Fredendall, 2009; Buch and Tolentino, 2006; Lee and Choi, 2006) Training (Choi et al., 2012; Lee and Choi, 2006; Kaynak, 2003; Jayaraman et al., 2012) Reward and recognition (Jayaraman et al., 2012; Kaynak, 2003) Communication (Lee and Choi, 2006; Choi et al., 2012; Jayaraman and Teo, 2010) Quality information (Zu et al., 2008; Kaynak, 2003; Lee and Choi, 2006) Specialist role structure availability and competency (Zu et al., 2008; Jayaraman et al., 2012) Culture (Zu and Fredendall, 2009; Jayaraman et al., 2012)	Six Sigma Resources/role structure (Zu et al., 2008) Method/tools (adherence of method/tools; knowledge in method/tools) (Choo et al., 2007;Linderman et al., 2006; Zu et al., 2008) Project goals (Challenging and specific) (Linderman et al., 2003, 2006) Focus on project metrics (Zu et al., 2008) Project leader's knowledge gathering behaviour (Sarin and McDermott, 2003; Hagen, 2010) Project leader experience (Easton and Rosensweig, 2012) Transformational leadership (Vera and Crossan, 2004). Transactional leadership (Vera and Crossan, 2004). Functional diversity (Ancona and Caldwell, 1992; Bunderson and Sutcliff, 2002)	Team psychological safety (Edmondson , 1999; Choo et al., 2007) Team work and team climate (Guitierrez et al., 2009, 2012) Performance goal orientation (Bell And Kozlowski, 2002; Seijts and Latham, 2005) Learning goal orientation (Bell And Kozlowski, 2002; Seijts and Latham, 2005; Gutierrez et al., 2012) Learning and knowledge creation (Anand et al., 2010; Wu and Lin, 2009; Choo et al., 2007; Choo, 2011; Gowen III et al. 2008; Sony and Naik, 2012) Learning behaviour (Anand et al., 2010; Choo et al., 2007; Choo, 2011) Absorptive capacity (Gutierrez et al., 2012) Project complexity and uncertainty (Nair et al., 2011; Shenhar,2001; Shenhar et al., 2002; Hagen, 2010)	Process improvement (Zu et al., 2008) Quality performance (Kaynak, 2003; Zu et al., 2008; Lee and Choi, 2006) Operational Improvement (Kaynak, 2003; Zu et al., 2008) Business performance (Financial and market) (Shafer and Moeller, 2012 Swink and Jacobs, 2012; Pulakanam, 2012; Kaynak, 2003; Choi et al., 2012)

Project Performance
(Anand et al., 2010; Choo et al., 2007; Linderman et al., 2006; Hagen, 2010)

Table 2.7 Measurement model

When the generation of defective products is reduced as a result of improved processes, manufacturing costs will be lowered, and the warranty and other administrative costs associated with activities like handling customer complaints will be reduced (Kaynak, 2003; Reed et al., 1996). As a result of quality improvement, the costs associated with processes such as handling and disposal of rejections, inventory carrying, and extra manpower for all these unnecessary activities are reduced. Realization of these costs (CoPQ) for each project is achievable soon after project completion. These indirect costs contribute toward improving revenue and thus on RoA, as confirmed by the findings of Swink and Jacobs (2012).

The multi-level framework shows the evolving interdependencies among various factors that are proven and are potentially linked with Six Sigma deployment and performance. Higher-level variables are hypothesized to influence/moderate the relationship between two or more lower-level variables. The model is complex, involving a number of relationships among variables from various levels, such as individuals, project teams, and organizations. The model posits a number of relationships that consist of numerous disciplines such as work motivation, behavioural operations, organizational development, operations management, and project management.

2.5.4 Summary of Chapter 2

The chapter consolidates a large body of knowledge on Six Sigma and its impact on performance based on a systematic review of the literature from 2000 to 2014. The review of Six Sigma literature has identified four streams of research and the researcher critically reviewed each stream of research and presented the views of the overall trend, findings, and shortcomings in each stream.

The systematic review is followed by a research synthesis, which is rare in reviews, especially in operations management and thus contributing to academic rigor. Overall, the finding of the review suggests that Six Sigma is indeed a business improvement strategy and a source of competitive advantage. The review clarifies that Six Sigma enhances business performance, and that Six Sigma implementation and the consequent operational and business performance are influenced by project by project success.

Beyond providing a systematic literature review, as an additional contribution the review provides a theoretically grounded multi-dimensional and multi-level framework, connecting three Meta constructs-managerial actions, project execution and organizational performance. This study (*study 1* of the dissertation), thus identifies Six Sigma as a multi-level phenomenon and suggests a unifying theory of Six Sigma linking organization (macro) and project (micro) levels. Discussions and implications for research and practice of this study will be included in chapter 9.

From the review and its findings, the researcher can conclude the following.

- The success of Six Sigma implementation is found to depend upon *project-by-project focus.*
- *The project success is mediated by learning and knowledge* creation in teams.
- Project performance is influenced by organizational and project level factors. Organizational factors refer to those elements that are governed by the actions of managerial personnel outside the project team; Project level factors are those factors that are characteristics of projects and are mostly governed or undertaken by project teams, both team leaders and members, and are characterized by actions within the project. The process model of Six Sigma is shown in figure 2.4.
- *Learning in Six Sigma team is intentional and deliberate* learning (Anand et al., 2009, 2010; Linderman et al., 2010; Llorens-Montes and Molina, 2006; Choo et al., 2007; Gutierrez et al., 2011; Wiklund and Wiklund, 2002)

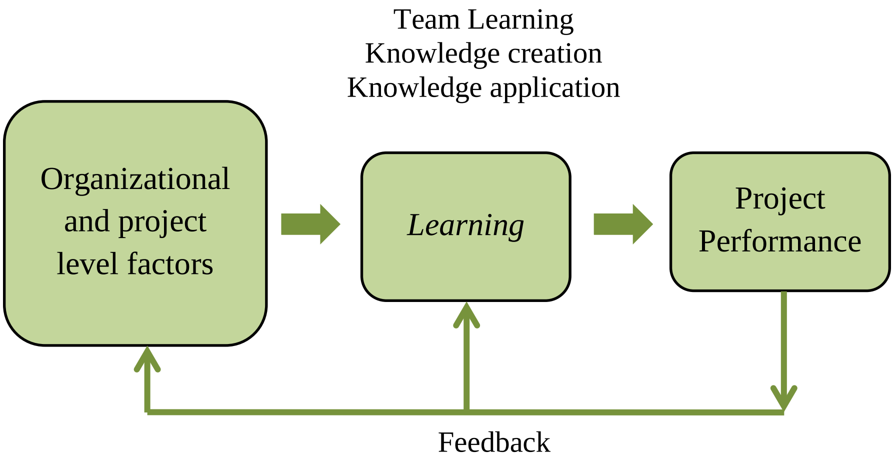


Figure 2.5 Process model of learning in Six Sigma projects

The review indicates that team while executing projects, learns, creates team level knowledge and using that new-found knowledge, solve problems, leading to improved project performance (Figure 2.5). The review further clarifies that the organizational and project-level factors influence learning in teams. The review reveals that factors such as a structured method, training, resources, role structure, psychological safety, information sharing, culture, and teamwork influence learning and knowledge creation in teams. Scholars have also suggested that factors, such as a project goal, project leader, and team structure may affect the team learning in projects.

If the progress of the project falls short of the expectation of the team, feedback is created that makes organizational and project level factors to react and impact learning in teams that further influence the performance. The project team is involved in intentionally changing of routines and procedures.

As the main objective of this research is to investigate learning in Six Sigma project team, the researcher intends conducting a focused review on learning in Six Sigma, which is the objective of the next chapter from which the researcher develops four specific research questions for further empirical research, and a research framework for guiding the research.

CHAPTER 3

A FOCUSED REVIEW ON LEARNING IN SIX SIGMA: RESEARCH GAP

The aim of this chapter is to identify any gaps in the body of knowledge on learning in Six Sigma improvement project teams. In doing so, the researcher develops four specific research questions for the research. In addition, this chapter intends to clarify how the main focus of the research ‘‘learning in Six Sigma project team’’ is positioned in relation to other related academic disciplines such as organizational learning and team learning. Insights from these literatures are considered in the process-based perspective of learning (input-process-output) in Six Sigma teams. Based on the review, the chapter also develops a research framework, and nine testable hypotheses.

3.1 Antecedents of learning in Six Sigma project teams

This section discusses the outcome of the focused review of learning in Six Sigma teams and factors that influence learning. In the Six Sigma context, learning is induced by a series of deliberate learning activities of the Six Sigma program. Members of the project team are given extensive training in problem-solving approaches. The project team brings in, different knowledge domains and individual members learn from each other and knowledge is shared widely among the members through various techniques adopted in DMAIC phases. The challenging improvement goals (stretch strategy) for projects motivate organizational members to engage in intentional learning activities that create knowledge and make improvements (Locke and Latham, 1990; Linderman et al., 2003, 2006; Choo, 2011).

3.1.1 Method and learning

The structured method (such as DMAIC) used in the project, which is embedded with relevant tools and techniques guides and facilitates team in collecting and analyzing data, getting insight into the process being investigated, and developing team level knowledge about the dynamic nature of the process and acquiring a better understanding of the relationships among process variables. Choo et al., (2007b) find that adherence to the method significantly affect learning behaviours. They argue that a structured method such as DMAIC provide a rational and systematic way of capturing and generating knowledge, and it represents a cognition-influencing mechanism that leads to learning behaviours and knowledge created in quality improvement teams. More specifically, problem-solving heuristics used in improvement projects help teams use the knowledge collectively to identify and analyze opportunities to improve the quality (Hackman and Wageman, 1995). Savolinen and Haikonen (2007) through a case study research, find that the learning process exhibited in Six Sigma characterized by measurement, direction and correction of errors, and cost reduction is supported through the DMAIC cycle. The method also is found to impact commitment to learning as evidenced from the recent study by Sony and Nike (2012).

3.1.2 Training and Role structure

Past research into Six Sigma context has shown that the coaching expertise of Black Belts in a Six Sigma project team is positively related to the project performance (Hagen, 2010; Arumugam, 2011). The role structure in Six Sigma facilitates a hierarchical coordination mechanism of work for quality improvement across multiple organizational levels, ensuring better work design and coordination capability (Sinha and Van de Ven, 2005; Zu et al., 2008; Van den Bosch et al., 1999; Kogut and Zander, 1992).

Research shows that differential training at different levels helps facilitate improved effectiveness in project teams due to knowledge creation (Linderman et al., 2003; Lee and Ebrahimpour, 1985; Lapré and Van Wassenhove (2001). Zu and Fredendall (2009) for example, found that employee involvement, training and performance and recognition have a positive effect on DMAIC. In related research, Zu et al. (2008) found that the Six Sigma role structure supports DMAIC, adherence to which promotes activities that meet the project goals, especially challenging goals, and help achieve project success (Chakravorty, 2009; Linderman et al., 2006). Recent empirical studies by Sony and Naik (2012) find that the role structure significantly affects organizational learning capability which comprises a commitment to learning, shared vision and open mindedness. In particular, specialists who lead project facilitates team members to attain skills in problem solving and to gain increased process knowledge (Wiklund and Wiklund, 2002; Linderman et al., 2006, 2010; Choo et al., 2007; Anand et al., 2009; Llorens and Molina, 2006, Savolainen and Haikonen, 2007). Project database helps the team with many suggestions and ideas for successful execution of their projects and thus knowing-what and knowing-how knowledge (Linderman et al., 2010).

3.1.3 Social and technical support

Based on the grounded theory study, Linderman et al. (2010) suggest that the leadership creates a supportive infrastructure enabling process improvement techniques to create organizational knowledge effectively. They find, that the leaderships of the case organizations in their study created conducive culture and organizational design involving parallel participation structure (specialist role structure), and provided resources for deployment (training, Information system support and dedicated human resources for project execution). Project goal motivates the team to put more efforts, and cross functional team facilitates collective mind for greater engagement. Linderman and his team argue that this social aspect of the project team interacts with the infrastructure (technical aspect) to engage in process improvement technique to create knowledge and solve the problem.

Building on the study of Mukherjee et al. (1998) who focus on the explicit knowledge transfer and creation and their effects on process improvement, Anand et al, (2010) studied the knowledge creation processes employed in Six Sigma projects and established that knowledge creation practices influence the success of the projects. Using Nonaka's knowledge-creation framework (Nonaka, 1991, 1994), Anand et al. (2010), focus on practices used by team leaders to capture both explicit and tacit knowledge of team members and create new *know-how knowledge* for process improvement. The researchers have established that Six Sigma project team, improvement methods used by the team, role structure and project leaders, create a conducive environment and procedures that support the transfer and creation of knowledge (both explicit and tacit knowledge) within the team to solve problems and improve processes. Likewise, Wu and Lin (2009) through case research, find that Six Sigma provides knowledge creation environment to facilitate knowledge creation through tacit and explicit knowledge transfer. The authors propose that external communication with the customer, management involvement, measurement of customer perception, infrastructure management (training and education) and process management all provide the proper environment to project teams to transfer and create knowledge.

3.1.4 Psychological safety and learning in teams

A psychologically safe atmosphere with a team makes a member, feel safe for interpersonal risk taking without the fear of negative consequences to self-image, status or career (Kahn, 1990; Edmondson, 1999). This psychological experience shapes the processes of people engaging in knowledge transfer among the team members (Edmondson, 1999; Tucker et al., 2007). If a conducive and comfortable team climate characterized by interpersonal trust and mutual respect in which people are comfortable being themselves exists, team members feel psychologically safe. This sense of safety called "team psychological safety" (Edmondson, 1999) is defined as a shared belief that the team is safe for interpersonal risk taking. When such an environment is present in the team, each team member feels a sense of confidence, and he or she feels the team will not embarrass, reject or punish him or her for speaking up. In such environments, members show interest in exchanging knowledge with fellow team members, and this enhances the conversion of individual knowledge into team-level knowledge. Thus, team psychological safety influences team learning behaviours. In Six Sigma context, Choo et al. (2007b) find that psychological safety influences knowledge creation and, in turn, performance in a project team. Psychological safety affects the team's cognitive ability to gain more insights and a collective understanding of the problems and issues with the process, enhancing knowledge creation (Choo et al., 2007b).

3.1.5 Teamwork

Gutierrez et al., 2011 empirically establish that teamwork and process management in the Six Sigma organization are found to influence organizational learning orientation through absorptive capacity. Absorptive capacity (AC) is defined as ''the ability of a firm to recognize new, external information, assimilate it, and apply it to commercial ends'' (Cohen and Levinthal, 1990:128). Gutierrez and his team argue that teamwork, which encourages team members to share expert knowledge to suggest and create new ways to improve processes Specialized role structure used in Six Sigma (champion, Black Belts, Green Belts, etc.) fosters the collective desire to learn to solve problems, and the resources made available to project teams support learning and knowledge (Choo et al., 2007a). Further the authors argue that challenging goals which enhances positive motivation among team members all positively affect AC which in turn impact learning orientation, which they conceptualize as the organization-wide activity of creating and using knowledge to enhance competitive advantage.

3.1.6 Focus on metrics

Six Sigma uses common metrics such as defect per million opportunities and sigma level, etc. These common metrics help coordinate knowledge creation efforts by integrating and aligning the problem-solving process (Choo et al., 2007a). These common metrics facilitate communication about problems and help uniform understanding across the organization and this further facilitates more consistency in the reporting, understanding and coordinating and problem-solving (MacDuffie, 1997). However, a recent study by Sony and Nike (2012) could not establish this relationship, but they find ‘focus on metrics’ impact only shared vision.

3.1.7 Project goal

Goals serve as a motivational mechanism that regulates human action (Locke et al., 1981). Challenging goals mobilize effort, direct attention, and encourage persistence and influences strategy development (Locke and Latham, 1990; Seijts and Latham, 2005). Locke and Latham (1990) assert that goals activate knowledge and skills that the individual possesses that are perceived relevant to the task. By drawing on goal-setting theory (Locke and Latham, 1990), Linderman et al. (2003) proposed a goal-theoretic model of Six Sigma and argues that specific and challenging Six Sigma goals lead to more effort, persistence and direction by team members than vague goals, resulting in improved performance levels. Subsequently, researchers tested the model empirically, and the result established that goals can be effective in Six Sigma improvement teams when they adhere to the Six Sigma method (Linderman, Schroeder, Zaheer, & Choo, 2006). Further, Linderman et al. (2003), noted that ‘‘improvement goals motivate teams to engage in intentional learning activities that create knowledge and make improvements’’ (Linderman et al., 2003, pp. 193-194). No study has investigated this possibility in the Six Sigma context, although industrial psychology literature shows some evidence that the goal motivates intentional learning (Kleingeld et al., 2011). It is then necessary to theoretically develop and empirically examine the effects of goal (social factor) on project performance through learning and knowledge.

3.1.8 Team structure

Members of the team actively teach and learn from each other and thereby enriching the total pool of knowledge and skills available (Llorens-Montes and Molina, 2006). In Six Sigma project, as members of the project team comes from different functions, they bring in different knowledge domains. As prior research in strategy literature has shown that cross-functional team facilitates the flow of information and knowledge across functional boundaries (Gupta and Govindarajan, 2000), the Six Sigma team can develop team-level knowledge through their interactions.

3.1.9 Project leader

Hoerl (2001) stated that project leaders are trained in the use of practices for collecting, combining, and synthesizing the knowledge of team members for use in process improvements, which has yet to be investigated and explicitly established. Research in new product introduction team has shown that project leader's characteristics lead to enhanced knowledge transfer and creation (Sarin and McDermott, 2003). In Six Sigma context, recent empirical study by the researcher has shown that the project leader's knowledge gathering behaviour enhances team learning and knowledge creation and in turn project performance (Arumugam, 2011).

3.2 Process model of learning in Six Sigma

From the review given above, the researcher can conclude the following. Factors that influence learning in Six Sigma teams:

Organizational level factors

- Supportive infrastructure:
- Role structure (Linderman et al., 2010; Zu et al., 2008)
- IT support (Linderman et al., 2010)
- Training (Linderman et al., 2010; Zu and Fredendall, 2009)
- Management team's support to project (Linderman et al., 2010; Zu et al., 2008)

- Use of metrics/Data (Choo et al., 2007; Linderman et al., 2010; Sony and Naik, 2012
- Organizational Culture (Linderman et al., 2010)

Project level factors

- Method (Choo et al., 2007; Savolinen and Haikonen, 2007; Sony and Naik, 2012; Linderman et al., 2010)
- Goal (Linderman et al., 2003, 2010)
- Project leader (Hoerl, 2001; Hagen, 2010; Arumugam, 2011)
- Cross-functional team structure (Llorens-Montes and Molina, 2006; Linderman et al., 2010)

Social factors:

- Psychological safety (Choo et al., 2007)
- Team work (Gutierrez et al., 2011; Malik and Blummenfeld, 2012)

Project outcome: Enhanced process capability, quality improvement and financial gains

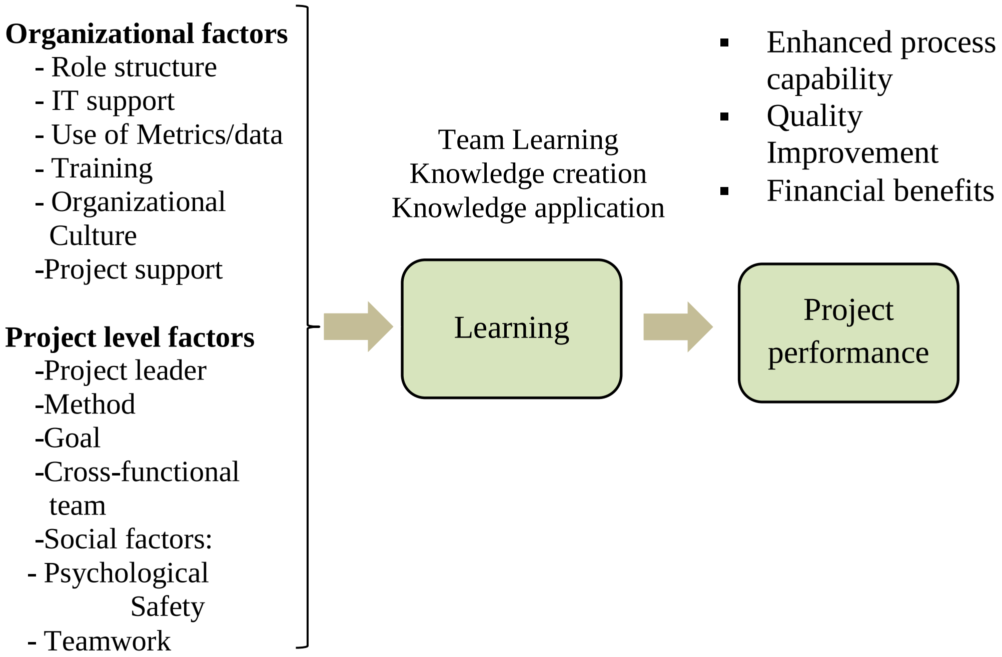


Figure 3.1 Process model of learning in Six Sigma team

The process model of learning in Six Sigma (Figure 2.4) after incorporating all factors identified from the review is given in Figure 3.1.

3.3 Team learning literature review

The review in the last chapter indicates that team while executing projects, learns, creates team level knowledge and using that new-found knowledge, solve problems leading to improved project performance. The project team is involved in intentionally changing of routines and procedures and hence team learning (Edmondson, 1999; Senge, 1990). The researcher, therefore, decided to get some insights into team learning literature that may shape the plan of research in investigating learning in Six Sigma project teams. Figure 3.2 shows the mind map representation of the studies reviewed in this focused review of team learning in Six Sigma.

Learning is a process of improving organizational actions through better knowledge and understanding (Fiol and Lyles, 1985). Huber (1991) asserts that the organization learns if any of its units acquires knowledge that it recognizes as potentially useful to the organization (Huber 1991. p. 89). Learning implies some positive change in understanding, knowledge, ability/skill, process/routines, or systematic coordination that impacts performance (Edmondson et al., 2007). While scholars argue that learning is an organizational phenomenon (Argyris and Schon, 1978; Huber, 1991), they contend that it takes place through individuals (Simon, 1991). It is further argued that organizational learning is not simply the cumulative result of each member's learning (Fiol and Lyles, 1985), but knowledge progresses from individual, move to (via) teams or groups and to the organization (Nonaka, 1994; Nonaka and Takeuchi, 1995; Conner and Prahalad, 1996; Grant, 1996; Kogut and Zander, 1992; Argyris and Schon, 1978; Huber, 1991; Crossan et al., 1999), through social interactions (Nonaka, 1994; Nonaka and Takeuchi, 1995). Teams are the fundamental learning units in organizations (Senge, 1990; Nonaka, 1994). Teams can be defined as work groups that exist within the context of a larger organization and share responsibility for a team product or service (Hackman, 1987). Teams are a design of choice for accomplishing work (Edmondson et al., 2007). Team learning is a process in which the team takes action, obtains and reflects on feedback, and makes changes to adapt or improve (Edmondson, 1999; Argote et al., 2000).

Learning in Six Sigma

Team Learning

Learning curve research
Argote et al. (2000)
Darr et al. (1995)
Lapre et al. (2000)
Lapre, Mukherjee & Van Wassenhove (2000)
Pisano et al. (2001)
Reagans et al. (2005)

Group Process
Bresman (2010)
Bunderson & Sutcliffe (2003)
Edmondson et al. (2001)
Edmondson (1999)
Edmondson (2003)
Edmondson (2007)
Gibson and Vermeulen (2003)
Lovelace et al. (2001)
Sarin and McDermott (2003)
Sole and Edmondson (2002)
Tucker et al. (2007)
Van der Vegt & Bunderson (2005)
Wong (2004)
Zellmer-Bruhn and Gibson (2006)
Zellmer-Bruhn (2003)

Task mastery research stream
Austin (1998)
Cannon-Bowers et al. (1993)
Gruenfield et al. (1996)
Hollingshead (2001)
Larson & Christensen (1993)
Liang et al. (1995)
Mathieu et al. (2000)
Moreland et al (1998)
Moreland and Myaskovsky (2000)
Stasser, Stewart & Wittenbaum (1995)
Wagner (1987)

Organizational learning
Argyris and Schon (1978)
Conner and Prahalad (1996)
Crossan et al. (1999)
Fiol and Lyles (1985)
Grant (1996)
Huber (1991)
Kogut and Zander (1992)
Nonaka and Takeuchi (1995)
Nonaka (1994)
Senge (1990)
Simon (1991)

Learning in Six Sigma
Anand et al. (2009)
Anand et al. (2010)
Choo et al. (2007)
Cho et al. (2011)
Gowen et al. (2008)
Guitierrez et al. (2009)
Gutirerrez et al. (2012)
Hoerl (2001)
Lee and Choi (2006)
Linderman et al. (2003, 2006, 2010)
Llorens-Montes and Molina (2006)
Malik and Blummenfeld (2012)
Savolainen and Haikonen (2007)
Sony and Naik (2012)
We and Lin (2009)
Wiklund and Wiklund (2002)

Figure 3.2 Mind map representation of focused review of learning in Six Sigma teams

The teams became the critical focal point in knowledge management (Argote, 1999; Nonaka and Takeuchi, 1995), and scholars took interest to know how members of newly formed teams learn to work together and how existing teams improve and adapt (Edmondson, 2002; Edmondson et al., 2007), and as a result team learning has acquired the prominence. Having emerged as a new topic in the management literature in the 1990s, team learning literature focuses on learning activities in terms of learning behaviours or activities adopted by the team members, and investigates how various organizational antecedents affect them.

The field is fairly young and fast growing and has expanded in the early 2000s and beyond. As against the dominant theoretical or conceptual focus in organizational learning research discipline, team learning literature registers a growing number of empirical studies (Edmondson et al., 2007). Evidence that learning affects team performance motivates scholars to undertake research to understand how team acquires knowledge (Edmondson, 1999). Understanding the factors that promote or inhibit these interactive learning processes within teams has, therefore, become an important research agenda for management scholars (Argote 1999, Edmondson 1999). The aim of this review of team learning literature is to explore what is known and unknown and to make use of the insights derived from the review to build on learning in Six Sigma teams.

Team learning literature spreads in various management disciplines such as manufacturing and Service operations (Learning curve research), social psychology and the organizational behaviour research (Edmondson et al., 2007). Each of the disciplines focuses different dimension of team learning and uses different lenses to study the phenomenon. Edmondson and her team through their extensive review of the current literature summarize three streams of research: outcome improvement, task mastery and group processes (Edmondson et al., 2007).

Table 3.1summarizes the fields of focus of each of the three streams. Learning curve studies examine efficiency improvement with little attention to group member perceptions or behaviour. The other two streams investigate how team member knowledge and interpersonal relationships affect group outcome.

Table 3.1Comparison of team learning research streams (adapted from Edmondson et al., 2007)

Concepts	**Outcome Improvement**	**Task mastery**	**Group process**
Focus	Improvement in efficiency	How do teams coordinate knowledge and skill to accomplish tasks?	What drives learning-oriented behaviours and processes
The concept of team learning	Learning is performance improvement	Learning is task mastery	Learning is a process of sharing information and reflecting on experience
Independent variable	Codified knowledge, shared ownership, team stability, knowledge sharing	Transactive memory system, communication	Team leader behaviour, psychological safety, team identification, team composition, organizational contextual factors
Dependent variable	Cost reduction or time reduction	Performance on a novel task	Learning behaviour or team effectiveness
Key findings	Working together in teams improves performance; how people work together, and how dimension of the improvement affect the rate of learning.	Coordinated ways of codifying, storing and retrieving individual knowledge is necessary to access individual knowledge for coordinated task performance.	How team leadership, team psychological safety, goals, and identity, promote team learning behaviour and in turn on performance
Research Methods	Field research: quantitative data from teams producing products or service	Laboratory experiments: student teams, and assigning conditions to establish causality	Field research: both qualitative and quantitative data from work teams

3.3.1 Learning curve research

Benefit of experience for efficiency is a major theme in most of the research in learning curve research stream in manufacturing and service, including hospital settings. This stream documents the link between cumulative production experience and operational performance. Most of the studies measure *learning in terms of efficiency improvement*. Knowledge acquired through experienced-based learning is presumed to be the mechanism explaining the difference in rates of improvement in performance. For example, a study by Lapre, Mukherjee &Van Wassenhove (2000) conducted in a steel wire manufacturer shows that improvement (waste reduction) occurred in projects characterized by both operational and conceptual learning activities.

Scholars also find variance in performance due to differences in the types of knowledge acquired such as *tacit* or *codified* (explicit) knowledge (Edmondson et al., 2003). Tacit knowledge is internal and not easily codified and requires individuals to accompany the knowledge, and difficult to transfer, whereas codified knowledge is easily transferable without face-to- face interaction. Further, in the context of health care settings, the researchers found that improvement in hospital surgery that required tacit knowledge was found to have associated with team composition stability. Reagans, Argote & Brooks (2005) through their study in hospital settings found that increased experience working together in a team promoted better coordination and teamwork. Evidence suggests that the rate of learning in a team is affected by how the learning process is managed (Pisano, Bohmer & Edmondson, 2001). Other studies demonstrate the notion that learning by doing is supported by team stability, team coordination, communication and team familiarity (Darr, Argote & Epple, 1995; Reagans, Argote & Brooks, 2005).

3.3.2 Task mastery research stream

The second stream of research conceptualizes team learning as task mastery and how well a team has learned its task. The primary focus in this stream is encoded, storing, retrieving and communicating information with teams. Researchers are treating *learning as an outcome* and measure it in terms of task performance, and how team members master the task. Data for the most of the studies are coming from laboratory settings (University students) and mainly the studies focus team level cognitive constructs that encode, store, retrieve and communicate knowledge and predict task performance (Hollingshead, 2001; Wagner, 1987). Main constructs found in the literature are shared mental models (Cannon-Bowers, Salas, Converse, & Castellan, 1993), Transactive memory systems (TMS) (Wagner, 1987; Liang, Moreland, & Argote, 1995, Moreland, Argote & Krishnan, 1998), Transactive memory accuracy (Austin, 1998) and social cognition (Larson & Christensen, 1993). Explicit recognition of members' task-relevant expertise also found to improve the team's task performance (Stasser, Stewart, & Wittenbaum, 1995). In a related study, Gruenfield, Mannix, Williams, & Neale (1996) show that when team members know each other, tacit knowledge is more likely to help team task than when they are unacquainted which is also supported by a later study by Moreland and Myaskovsky (2000). However, certain team characteristics such as team size, turnover and expertise-diversity may promote or inhibit Transactive memory system and team processes mediate the relationship between Transactive system and task performance (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000).

3.3.3 Group Process

This stream of research conceptualizes *team learning as a group process*. The stream employs Input-Process-Output model in which *group interaction processes* mediate the relationship between group inputs and group outputs. Input includes context, structure, and composition; output includes quality, innovation and performance. Most of the studies focus on the process of learning as evidence that learning has occurred rather than relying on performance improvement.

Understanding the factors that promote or inhibit these interactive learning processes within teams has therefore become an important research agenda for management scholars (Argote 1999, Edmondson 1999). A growing number of studies investigates learning processes and how they are affected by managerial and contextual factors. Recent studies examine the effects of team leader behaviour (Sarin and McDermott, 2003), group climate, team effectiveness, team psychological safety (Edmondson, 1999), contextual factors such as the importance of the project to the organization, project risk and complexity, and team size.

Edmondson (2003) asserts that team leaders play a critical role in helping their team members frame and reframe knowledge and experience. Lovelace, Shapiro, & Weingart (2001) suggest that the characteristics of team leaders significantly affect the work climate and learning in teams. Building on these, Sarin and Mc Dermott (2003) from the data collected from 52 new product development teams, showed that team leader behaviour such as involving members in decision making, clarifying team goals, and providing bridges to outside parties via the leader's status in the organization facilitated team learning. Satin and McDermott (2003) suggest that participatory behaviour by the team leaders encourages team members to take a broader view of their jobs and consider a wider variety of information, inputs, and constraints in their decision making process leading to the free exchange of ideas and cross functional knowledge fertilization. Team size has negative influence on team learning, and Sarin and Mc Dermott suggest that as team size grows, more time and effort is spent on process and coordinating activities rather than addressing the problem and hence learning. Team learning was more extensive when the project was important to the organization.

3.3.4 Learning behaviours and performance effects in team learning literature

Recent studies in this stream look into detailed aspects of learning behaviour in different research settings. Edmondson, Bohmer, & Pisano (2001) for example identified four steps of learning process in teams that involve in the new surgical implementation in hospitals: *enrollment, preparation, trials, and reflection*. Gibson and Vermeulen (2003) in the context of pharmaceutical and medical product firms, conceptualize team learning as the product of *experimentation, reflective communication, and knowledge codification*. Sole and Edmondson (2002) while investigating learning in globally dispersed new product development teams, proposed that team learning involves figuring out how to recognize and access *situated knowledge* embodied in different facilities and locales.

(Wong 2004) studied recently team learning in 73 teams from 4 organizations, by measuring *local* learning (learning from interactions within a group), and *distal* learning (learning by seeking ideas, help, or feedback from external parties) and their effects on team performance (efficiency and innovation). Wong also investigated the influence of group cohesion (strength of intra-team relationship) and task condition on team performance. The results suggest that group cohesion promoted both local and distal learning which have shown differential effects on performance. Local learning predicted group efficiency and distal learning predicted group innovation. Wong recommended that teams responsible for task mastery should focus on local learning, and teams responsible for innovation should focus on distal learning.

Recent study by Tucker et al. (2007) on hospital improvement teams in intensive care unit found that *learn-what* learning behaviour (learning activities that identify current best practices by drawing experience from other teams, hospitals or literature) did not influence implementation success whereas *learn-how* learning behaviour (activities that operationalize practices in the work settings) did. One possible explanation could be that learning in intensive care units requires more internally focused learning behaviour.

While investigating learning in 16 operating room teams engaged in new technology implementation in cardiac surgery, Edmondson (2003) developed two learning behaviours using data from a qualitative study: *Incremental learning*: doing things better, execute and improve existing capabilities, and *Radical learning*: Doing new things, explore and develop new capabilities. The subsequent quantitative study established that teams were iterating between incremental and radical learning to produce change Teams exhibited reflection and change /reflection without any change. The power of team leader also found to inhibit learning in teams.

3.3.5 Context in team learning

Recent studies focus on context, both internal and external to the team, and establish some striking findings that show that the contexts in which the team operates has a fundamental influence on team learning behaviours. Organizational context is a‘‘set of overarching structures and systems external to the team that facilitat or inhibit its work’’(Denison, Hart, Kahn, 1996: 1006). Edmondson asserts that each context represents qualitatively distinct aspects and each aspect can have different effects (Edmindson, 2003). These external contexts can be near to a team boundary or away from it socially or physically and may include formal work unit such as department, business units and organization (House, Roussseau & Thomas-Hunt, 1995). Zellmer-Bruhn and Gibson, 2006, studied 115 teams from five multinational firms and found that a learning outcome defined as, ‘‘the extent to which the team created new processes and practices'' was more likely to occur in less-centralized organizations where teams are granted decision-making autonomy by the global and local organizations.

Research in this stream also identifies that micro contexts influence team learning. Leader characteristics (Sarin and McDermott, 2003), performance management by an external leader, empowerment (Gibson & Vermeulen, 2003), leader facilitation and coaching (Edmondson, 1999, 2003), training, information and assistance (Edmondson, 1999), disruptions in a team's micro context (Zellmer-Bruhn, 2003), team autonomy and organizational experience (Hass, 2006) are also some of the micro contexts which have shown to influence learning behavior in teams. Micro contexts are likely to vary among teams within a business unit or a firm and often change and evolve through team response and input (Zellmer-Bruhn and Gibson, 2006). Existing studies on macro context is sparse in team learning literature (Zellemer-Bruhn and Gibson, 2006). However a number studies in creativity and innovation literature focus on macro contexts (Amabile, Conti, Coon, Lazenby, Herron, 1996). Some of the macro contexts are culture, resources, strategy, structure, and focus on technology influence (Perry-Smith and Shalley, 2003), rewards (Eisenberger & Armeli, 1997), and job complexity (Oldham & Cummings, 1996).

Table 3.2 summarizes some of the recent studies in this stream of research showing learning mechanism conceptualized and measured and performance consequences established in each study. Studies also investigate the effects of various organizational contextual factors, which affect the influence of various learning activities on team performance. The most of the empirical studies directly investigate the relationship between learning behaviors and task performance in teams. Task performance relates to how well a team-perform and meets its goals and how well the output fulfils the team's mission (Hackman, 1987).

Table 3.2 Sample of studies on team learning: Learning behaviours and performance consequences

Authors	Data and method	Learning behaviours	Predictors/ context variables	Key findings
Edmondson (1999)	53 work teams from a manufacturing firm Survey, interview and observation	Learning behaviours	Psychological safety Team efficacy Leader coaching Context support	Team design and leadership influence psychological safety, which impacts learning behaviour and in turn performance
Edmondson (2002)	Qualitative data 12 manufacturing companies. Teams: management, product development, service and production	Incremental learning: doing things better, execute and improve existing capabilities Radical learning: Doing new things explore and develop new capabilities.	Perception of Power and hierarchy, Interpersonal risk.	Iterating between incremental and radical learning to produce changes. Teams exhibit reflection and change /reflection without any change. The power of team leader also inhibits learning in teams.
Edmondson (2003)	Qualitative and quantitative data from 16 operating room teams engaged in new technology implementation in cardiac surgery.	Learning behaviours: Ease of speaking up, boundary spanning, practice and reflection	Psychological safety Team leader actions Contexts: Resource, information, management support, innovation history	Effective team leaders fostered "speaking up in the service of learning", by motivating the need for learning and deemphasizing power differences.
Bunderson & Sutcliffe (2003)	44 management teams from a business unit of a large consumer product organization Survey	Team learning orientation: an emphasis on proactive learning and skill development in a team	Past performance	The relationship between team learning orientation and performance is non-monotonic and moderated by past performance, with the optimal level of performance was higher for teams with lower prior-period performance.

Gibson and Vermeulen (2003)	156 teams from medical products and pharmaceutical firms Survey and interviews	Learning behaviour: experimentation, reflective communication, and knowledge codification.	Subgroup strength (degree to which some pairs of team members share demographic characteristics not shared with others), Performance management by external leader, Team empowerment (autonomy), Availability of knowledge management system.	Subgroup strength was a moderator of external leader-team empowerment and the availability of knowledge management system. Subgroup strength was a better predictor of performance
Sarin and McDermott (2003)	52 New Product Introduction team (229 members) from six high tech companies, Survey research	Learning behaviours	Leader characteristics (consideration, participation, initiation of goal structure and process structure, and leader position)	Leader characteristics influence team learning and in turn on team performance (innovativeness and speed to market).
Zellmer-Bruhn (2003)	Qualitative data: 46 teams from 3 firms from pharmaceutical and medical products. Survey data from 158 teams from 3 organizations	Knowledge transfer efforts: searching for new routines from external sources	Interruptions	Interruptions and knowledge transfer efforts are positively related to the acquisition of new work routines.
Wong (2004)	73 teams from 4 organizations	Local learning, Distal learning	Group cohesion (strength of intra-team support) Task condition	Local learning predicted group efficiency Distal learning predicted group innovativeness Group cohesion impacts distal learning. Group cohesion negatively influences distal learning

Van der Vegt & Bunderson (2005)	Surveys of members and supervisors on 57 teams; archival data.	Learning behaviours (activities by which team members seek to acquire, share, refine, or combine task-relevant knowledge through interaction with one another)	Team identity, expertise-diversity	Collective team identification moderates the effects of expertise-diversity on learning behaviour and performance. Team learning mediated the effects of diversity and performance.
Zellmer-Bruhn and Gibson (2006)	Surveys of 115 teams and their external supervisors; archival data. Wide range of teams from 5 multinational pharmaceutical and medical products firms.	Learning: "the extent to which team created new processes and practices"	Team autonomy	The autonomy granted by the organizational context can constrain or enable team innovation and learning.
Tucker et al. (2007)	23 hospital improvement project teams Survey and interviews	Learn-what and Learn-how	Psychological safety	Learn-how learning behaviour mediated the relationship between psychological safety and implementation success. Learn-what activities had no impact on success.
Bresman (2010)	62 teams from six pharmaceutical firms	External learning activities: Vicarious learning (learning from external experienced others about a task) and Contextual learning (learn from external sources about its context)	Internal learning activities	The two learning activities put different demands on team to become effective. Vicarious learning activities are more strongly associated with performance when teams engage in more internal activities; The positive performance associated with contextual learning activities is unaffected by the level of internal learning activities.

3.3.6 Summary of team learning

The review suggests that work teams can differ considerably in the extent to which they pursue activities and routines related to learning and continuous improvement. The routines vary from team to team, depending upon the nature of task, types of the team (short term vs long term, knowledge intensive, improvement or problem solving), composition of teams, nature of goals (achievable, difficult etc.), the context in which team operates, resources made available to teams, and objective of the teams. Hence, we find different mechanisms of learning in a variety of settings. The review also suggests that defining learning behaviour requires greater specificity and precision about team type and organizational context. For example, innovation teams will engage in more learning behaviours than routine production teams. Learning activities will also be different between these two teams. Likewise, process improvement teams will engage in various learning behaviours when compared to the production team. A team whose task is more on knowledge than actions, for example, will have different learning behaviours than a team with more diverse expertise. New product development teams, for example, may encounter in designing a new product radically or improving an existing product, and accordingly, learning in these teams will be either exploration or exploitation (Tatikonda, 1999).

The researcher, therefore, can conclude the following from the review of team learning literature:

- Learning behaviours of the team (activities or routines) vary from team to team (Edmondson, 1999; Edmondson, 2002; Edmondson et al., 2003; Sarin and Mc Dermott, 2003; Zellmer-Bruhn and Gibson, 2006; Wong, 2004; Tucker et al. (2007).
- Increasingly, learning is conceptualized and measured in terms of team level routines and processes in acquiring knowledge; this emphasis on process derives from team *effectiveness research and field-based methods to understand how teams learn* (Edmondson et al., 2007; Wong, 2004; Tucker et al. (2007)
- There is increasing evidence that team learning activities mediate the relationship between team inputs, such as composition, structure and context, and team outputs, such as innovation, efficiency and quality (Edmondson et

al., 2007; Zellmer-Bruhn and Gibson, 2006; Wong, 2004; Tucker et al. (2007).

- The relationship between learning behaviours and performance is not always positive, as it depends on the nature of learning behaviours (Wong, 2004).
- The review of team learning literature also points out different types of learning as relevant for various types of performance outcomes.

3.4 Why a study on learning behaviours in Six Sigma is required? -Research gap

Although we find a number of studies identifying learning behaviours and their antecedents and performance consequences in teams such as hospital improvement teams and new product development teams, there is a paucity of such research in process improvement teams such as Six Sigma project. Learning behaviours of Six Sigma teams are expected to be distinct, as the nature, composition, purpose, operating style, and project duration are different from that of other teams that have been investigated in the literature. Literature has yet to define and measure the learning behaviours of Six Sigma team. There is, thus, the research gap in the literature to identify learning behaviours and empirically establishing the factors that influence or inhibit learning behaviours in Six Sigma project team. Evidence from team learning literature suggests that explicit understanding of learning behaviours will help us identify factors that influence learning and will provide guidance toward managing learning and knowledge creation in Six Sigma teams which can provide information on how to enhance project performance.

The researcher thus concludes that there is a research gap about various learning behaviours that Six Sigma project team practice and how they influence project performance. Consequently, the broad research question that has emerged from the review and specific research questions (*RQ1* and *RQ2*) that follow it can be summarized as below.

***Broad Research question**: How does learning take place in Six Sigma project team?*

RQ1: What are the different learning behaviours or activities exhibited by project teams?

(Actions)

RQ2: How do the learning behaviours of project team impact project performance?

(Actions →Performance)

Numerous inefficiencies in the functioning of teams may be avoided if critical factors that inhibit learning are identified and suitable remedial measures are taken to reduce or eliminate the effects of these inhibitors. As the researcher's philosophical stance is positivism, he is interested in establishing the causal relationships among variables that may influence learning behaviours and knowledge and in turn on the performance. Hence, he intends to investigate the effect of some of the critical managerial factors in Six Sigma context that are likely to impact learning behaviours and knowledge creation in Six Sigma teams. Thus the emergence of the research question *RQ3* and *RQ4*.

Research question 3*: *How do managerial factors impact learning behaviours and in turn on project performance?

(**Causal linkage: Antecedents →Actions →Performance)**

Considering time, efforts, and resources available for the researcher, the study is restricted to four critical managerial factors from those which have been identified in the process model (Figure 3.2): Resources for the projects (training, role structure, IT support, management support for projects); structured method, project leader, and team psychological safety. The research investigates the impact of these factors on learning behaviours and project performance. The answer to this question will explain and predict the relationship and examine if any systematic effect is identifiable.

Although the ‘‘goal-performance’’ relationship has been established through empirical study in Six Sigma context (Linderman et al., 2003, 2006), we know very little about the theoretical mechanisms that may underlie it. No studies have explored this research to date, which is surprising given the fact that challenging goals are a special characteristic of Six Sigma deployment (Pande et al., 2000; Linderman et al., 2003). Goal theory literature suggests that challenging goals for the project team may motivate members to engage in learning and solve problems (Locke and Latham, 1990; Choo, 2011). In the context of Six Sigma, Linderman et al. (2003) noted that ‘‘improvement goals motivate teams to engage in intentional learning activities that create knowledge and make improvements’’ (Linderman et al., 2003, pp. 193-194). It is then necessary to theoretically develop and empirically examine the effects of goal (social factor) on project performance through knowledge. Given the fact that an earlier study by Linderman et al. (2006) showed that the Method (technical factor) used in Six Sigma projects moderates the ‘‘goal-performance’’ relationship, our next research question would be how Method moderates the goal-knowledge-performance. Hence our research question:

***RQ4**: How do social and technical aspects of project execution interact to impact project performance through learning and knowledge creation?*

(Causal linkage: Antecedents/Context →Action →Performance)

Since social and technical systems jointly optimize in any organizational systems, this question will be investigated in the context of Sociotechnical Systems (STS) theory. This theory advocates clear linkage between technical and employee involvement for enhanced organizational effectiveness (Lawler, 1992), and proposes that joint optimization of the social and technical components of the work systems is considered to be more desirable than simple optimization of either system at the expense of others (Cummings, 1978, Emery and Trist, 1969; Cherns, 1978). The investigation of this research question will be explained using the STS theory in Chapter 7.

3.5 Underlying theoretical Framework: A process based approach

Building on the findings of the Six Sigma literature and taking insights from team learning literature, the process model of Six Sigma can be shown as in Figure 3.3, which is our conceptual research framework. Learning' in the box of Figure 2.6 is replaced by 'learning behaviour' in Figure 3.3 consistent with our argument given in this section. The conceptual framework incorporated with the four research questions is shown in Figure 3.4

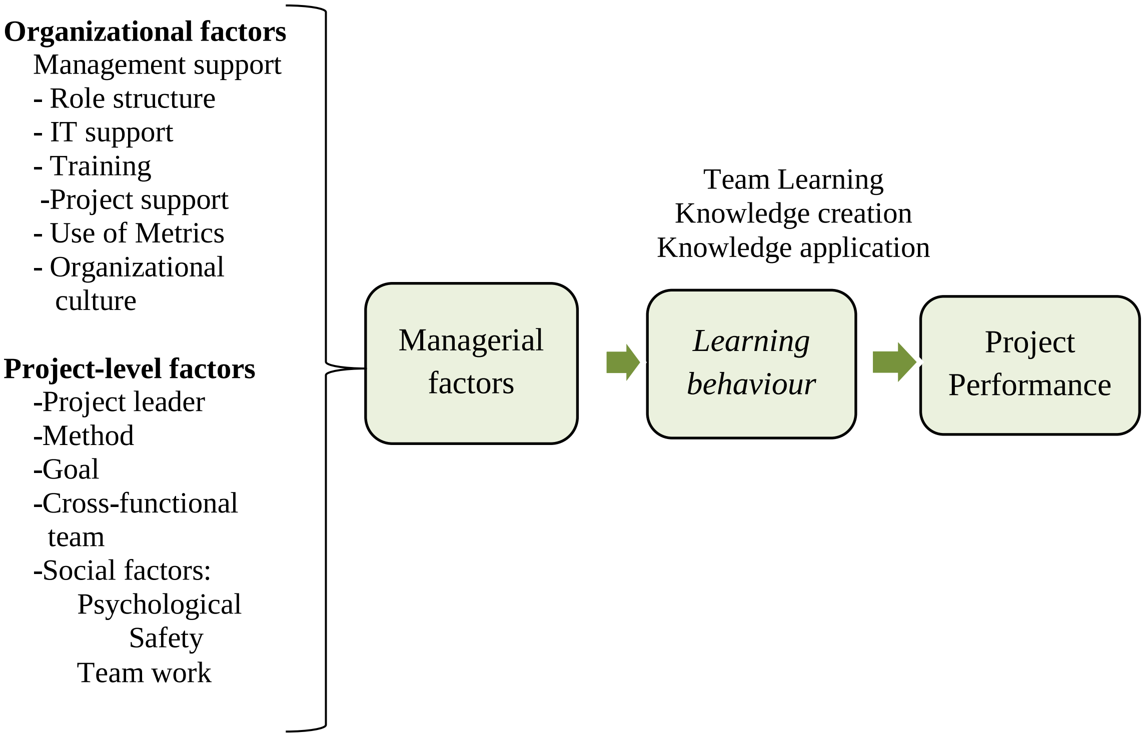


Figure 3.3 Conceptual framework

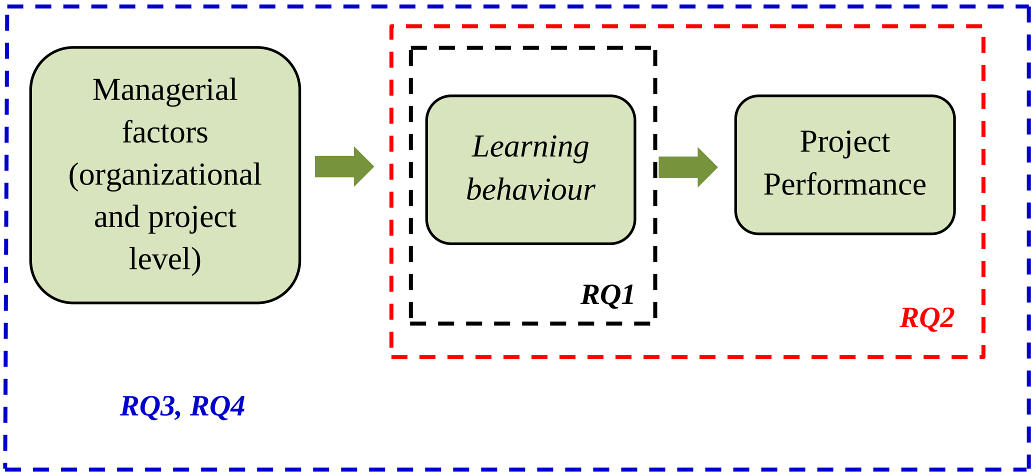


Figure 3.4 Conceptual framework showing research questions

These research questions will be addressed through empirical research. To make it easier for the reader to follow the reasoning in this study, the researcher wants to be explicit in his way of approaching his research process. Researcher's conception of learning behaviour is certainly not unique. It is in the tradition of team learning literature. Studies that focus on learning behaviour in real teams conceptualize learning as a group process rather than as a group or team outcome. Building on models, constructs and methods for research on organizational learning and team effectiveness, this stream of research employs an input-process-output model. Following this tradition, the researcher attempts to measure the process of learning and knowledge creation as evidence that learning has occurred. The process model (framework) assumes that learning processes are affected by managerial and contextual factors (such as resources, management support, goals and team social factors) and, in turn, learning processes affect team performance. Consistent with the team learning literature, the researcher planned to carry out field base research to understand how team learns by investigating all learning practices in project teams.

3.6 The purpose revisited

After the extensive discussion of theory relating to learning in Six Sigma teams, through literature review, it is time to revisit the research purpose set out at the very beginning of the my research journey, and to see how it can be practically fulfilled. The purpose of the research as stated in the first chapter ran as follows:

The purpose of the thesis is to understand the learning process in Six Sigma project teams. It includes conceptualizing learning process through process based approach as well as shedding light on how the learning behaviours affect project performance and factors that influence the learning behaviours.

The literature lacks the investigation into various learning activities, their antecedents, and performance consequences compared to other project teams such as hospital improvement teams and new product development teams as evidenced from team learning literature. Since style, structure, and purpose of Six Sigma team is different compared to other teams, there is a need to develop more refined and applicable model tailored to the Six Sigma project context that is grounded in practices. Based on the identified research gaps, a set of four research questions was developed for further empirical investigation (*RQ1, RQ2, RQ3* and *RQ4*), all relating to the relationship between learning and knowledge creation, managerial factors and project performance. A conceptual research framework to guide data collection and analysis was also formed based on the review and by using process-based model: *'input-process-output'*.

In order to have some guidance for data gathering and the initial interpretation of data, it is necessary to specify more precisely what to look for in the field work. Building on the previous theoretical discussion in this chapter, the researcher summarizes the research questions along with what he is going to look for during his data collection and what to accomplish by answering each research question.

Research Question 1: *What are the different learning behaviours or activities exhibited by the project teams?*

This research question aims to clarify all the primary activities or routines within the team during the project execution toward acquiring knowledge that helps to solve problems and implement solutions and accomplish the project goal. Each activity helps to clarify teams to understand the process, various input variables that affect output variables (CTQs), and their relationships. These activities help team members in searching for and acquiring knowledge from members both within and outside the team, synthesize to team level knowledge to generate solutions, and implement ***(Description).*** *The research inquiry will be to identify learning behaviours that team members exhibit toward learning in order to solve problems and implement workable solutions that satisfy all stakeholders.* The answer to the research question will be developed through a focused literature review.

Research Question 2: *How do the learning behaviours of project teams impact project performance?*
(**Causal linkage: Actions →Performance)**

The main objective of the Six Sigma improvement project is to achieve the project goal. Process perspective suggests that for every process, there are inputs and outputs, and they are related, and the relationship is predictable. This research question aims to shed light on the linkage 'learning behaviour-project performance'

(Causal linkage). Based on the existing research on Six Sigma and team learning research, develop measures for various constructs for learning behaviours and carry out quantitative data collection and analysis to investigate relationships between learning behaviours and project performance through a ***hypothesis (H1)*** which will be developed later in this chapter. *H1* aims to examine the causal relationships for explaining and predicting the relationship between learning behaviours and project performance ***(Explaining and predicting causal linkage)***

Research Question 3: *How do managerial factors impact learning behaviours and in turn project performance?* The answer to this question will explain the relationships between learning behaviours and antecedents and project outcome.
(**Causal linkage: Antecedents →Actions →Performance)**

The research question aims to investigate the impact of the managerial factors on learning behaviours and project performance. The researcher is of the view that all factors in the conceptual framework are of equal importance for the investigation. Although the researcher can consider all the factors found in the conceptual framework, considering the time and resource limitations, in agreement with the supervisor, it was decided to investigate only the following four managerial factors leaving the rest of the factors for a future research. (1) Resources (training, role structure, IT support and management support); (2) team psychological safety; (3) method; and (4) project leader. Of the four factors, three are project level factors and one is a managerial factor.

Based on the literature, the researcher developed/adopted measures for various constructs, collected data through a survey and carried out quantitative analysis (regression analysis) to establish hypothesized relationships between factors (***Hypotheses H2, H3, H4, and H5***). These hypotheses, developed in the next section, aim to investigate the causal relationships for explaining and predicting the relationship ***(Explaining and predicting causal linkage)*** between the four managerial factors and learning and performance.

Research Question 4*: How do social aspects of project team (goal) and technical aspects of project execution (method) interact to impact project performance through knowledge creation?*

(**Causal linkage: Antecedents & contexts →Actions →Performance**).

The research question aims to investigate a theoretical mechanism underlying the 'goal-performance relationship' in Six Sigma teams by incorporating knowledge as a mediator in the ‘‘goal-performance’’ relationship. The answers to this question add to the discussion about the complementary impact of social (motivational factor: project goal) and technical (method used in the project) factors using ***Sociotechnical system theory*** and ***Goal theory (under what contextual conditions?).*** Field work involves collecting relevant data and quantitative analysis to establish the relationships between goal, method, knowledge and performance (***Hypotheses H6, H7, and H8)***.

3.7 Hypotheses

Building on earlier theorizing of team learning, this section conceptualizes learning that takes place in Six Sigma projects into two distinct learning behaviours, *Knowing-what* and *Knowing-how*. Testable hypotheses are developed linking the two learning behaviours and project performance with the following four managerial factors.

1. Six Sigma resources (technical factor: organizational level factor)
2. Team psychological safety (social factor: project level factor)
3. Project leader behaviour (project level factor), and
4. Structured method (technical factor: project level factor)

3.7.1 Learning in Six Sigma versus learning in other teams

The review of team learning literature (refer Table 3.2) finds that team-learning activities mediate the relationship between team inputs, such as composition, structure and context, and outputs, such as innovation, efficiency and quality (Edmondson et al., 2007; Edmondson, 1999; Sarin and McDermott, 2003; Gibson and Vermeulen, 2003; Bunderson and Sutcliffe, 2003; Wong, 2004; Zellmer-Bruhn and Gibson, 2006; Tucker et al., 2007).

Two things need to be elaborated regarding these studies. First, the relationship between learning behaviours and performance, is not always positive, as it depends on the nature of learning behaviour (Wong, 2004) and the current level of performance (Levinthal and March, 1993; March, 1991). It may be possible for a team to compromise performance by overemphasizing learning, particularly when they have been performing well (Bunderson and Sutcliffe, 2003). Furthermore, not all learning may translate into organizational knowledge as members may fail to communicate with others for use (Ancona and Caldwell, 1992). Thus, “organizational knowing” does not always translate into “organizational doing” (Pfeffer and Sutton, 2000; Maier et al., 2001). For the purpose of this research, the researcher takes the position of many recent studies that learning results in improved performance (Edmondson, 1999, 2002; Edmondson et al., 2003; Sarin and McDermott, 2003; Tucker et al., 2007; Choo et al., 2007). Learning is a process of improving organizational actions through better knowledge and understanding (Fiol and Lyles, 1985). Huber (1991) asserts that the ‘‘organization learns if any of its units acquires knowledge that it recognizes as potentially useful to the organization’’ (Huber 1991. p. 89). Learning implies some kind of positive change in understanding, knowledge, ability/skill, process/routines, or systematic coordination that impacts performance (Edmondson et al., 2007). In Six Sigma context, problem-solving heuristics such as the DMAIC structured method used in projects help teams use the knowledge collectively to identify and analyze opportunities to improve the quality (Hackman and Wageman, 1995).

Second, the conceptualization and operationalization of measures of learning are not the same across all these studies and do not converge; therefore, theory building is problematic (Edmondson et al., 2007). On the one hand, similar measures are used to represent conceptually different things, such as learning (Zellmer-Bruhn and Gibson, 2006), innovation (Wong, 2004) and experimentation (Gibson and Vermilion, 2003), and on the other hand, different conceptualizations such as group interaction processes (Van der Vogt and Bunderson, 2005), the extent to which a team creates new processes and practices (Zellmer-Bruhn and Gibson, 2006), respondent’s perceptions of their future learning behaviour in the team (Sarin and McDermott, 2003), team activities such as reflection on group processes and discussions with outsiders (Edmondson, 1999), and identifying best practices and discovering the underlying root causes to implement new processes (Tucker et al., 2007) are used to mean learning.

Six Sigma requires different treatment in comparison to other teams, such as new product development, hospital improvement and information technology implementation teams. Six Sigma project teams are temporary, formed to improve a particular process, and have a short project duration (generally 3 to 6 months) (Antony, 2007a; Pande et al., 2000; Pyzdek, 2003). Except for the project leader, members contribute only a fraction of their work time. Therefore, social ties are not as close as in other project teams (Anand et al., 2010). Learning and knowledge transfer, therefore, is through specific practices used by the Six Sigma project team during the project such as DMAIC method, and project leaders' knowledge-gathering behaviour in gathering individual knowledge and synthesizing into team-level knowledge to solve problems (Arumugam, 2014; Anand et al., 2010; Sarin and McDermott, 2003). Consequently, learning mechanisms or behaviours, and the nature of social interactions and their effects on these learning behaviours show greater variance than that of other teams.

3.7.2 Knowing-what and Knowing-how learning behaviour

The researcher conceptualizes learning that takes place in Define and Measure phase of the DMAIC and learning that takes place in Analyze, Improve and Control phase as Knowing-what and Knowing-how respectively:

> *Knowing-what*, a learning behaviour that facilitates project team to understand the current process and its input factors (process characterization) and
> *Knowing-how*, a learning behaviour that helps the project teams identify how input factors affect process outcome and assist the team generates optimal solutions by changing or modifying input factors for improved process outcome (process optimization).

The above conceptualization of learning and knowledge creation in this research is different from the usual conceptualizations found in earlier research, as it represents the knowledge brought into projects through Define and Measure, and

Analyze, Improve, and Control phases of a Six Sigma project. The conceptualization of knowing-what and knowing-how thus refers to ‘‘input’’ knowledge (learning that goes into project execution) as opposed to ‘‘outcome’’ knowledge (learning that comes out of projects). Past research, for example, conceptualizes knowledge as an outcome, such as new ideas, improved understanding and enhanced capability of the project teams (Choo et al., 2007; Choo, 2011). Similarly, know-what and know-how (and know-why) refer to the outcome of the projects (Kim, 1993; Leonard-Barton, 1990; Mukherjee et al., 1998)

Given that learning behaviours vary depending upon the type of team, the nature of the task and the context of the team, earlier research in team learning literature conceptualizes different learning mechanisms, such as radical and incremental learning in organizational teams (Edmondson, 2002), learning-what and learning-how in hospital teams (Edmondson et al., 2003), local and distal learning in functional and cross-functional teams (Wong, 2004), and learn-what and learn-how in hospital process implementation teams (Tucker et al., 2007). Learning that helps an organization to explore and develop new capabilities is radical learning, while learning that helps to execute and improve existing capabilities is known as incremental learning (Edmondson, 2002). For example, learning activities that assist in creating new strategies (by top management teams) or developing new products can be radical learning. Learning that helps to execute and improve existing operations by modifying processes through the DMAIC method is an example of incremental learning. Incremental learning will result in improved efficiency and reduced cost and thus improvement of existing organizational capabilities.

The present conceptualization of knowing-what and knowing-how falls into incremental learning activity category. This conceptualisation is similar to Tucker et al. (2007) study, where learn-what (activities that identify current best practices) and learn-how (activities that operationalize practices) learning mechanisms were used in the context of healthcare process improvement team.

Scholars state that knowing is much more than knowledge. In Six Sigma project, the project team converts individual knowledge into collective team knowledge and uses that new knowledge in action and as a tool for further knowing. That is the team uses its new-found knowledge as tools for interacting with the process under investigation and one another in an instance of productive inquiry. Improving a process, for example, is not the result of just acquiring new or more knowledge by the project team, but the result of developing innovative ways of using the knowledge (solving problems). This, in a problem-solving context, generates new knowledge and new forms of knowing. Here, knowledge refers to what people possess, and knowing is something that is part of human action, referring to the ways team members deploy knowledge in their interactions with contexts, including what they do as well as what they possess (Cook and Brown, 1999). Thus, knowing-in-perspective aims to connect both individual and collective dimensions (Gherardi, 2006; Bouty and Gomez, 2010). Further, knowing is part of dynamic human action and takes place in the dynamic interaction with the world, and hence knowing is a dynamic creation (Gherardi, 2006; Nicolini et al., 2003). The conceptualization of the two learning behaviours incorporates inquiry, such as discussions among selves and with knowledgeable people, and reflection and taking action. These behaviours make the team use knowledge in new, innovative and more productive ways.

By sharing known and acquired knowledge about the process under investigation, team members, deduce unknown consequences and come to a broad and collective understanding of the entire process, its interfaces, and various influencing factors that affect the process output. The researcher refers to this learning behaviour that takes place during the Define and Measure phases of DMAIC as knowing-what, parallel to operational learning (Kim, 1993). Various learning activities and their effects are shown in Table 3.3. Teams draw different forms of knowledge from various sources. In summary, the team attains skills in problem solving and gains basic understanding of the process under investigation. With knowing-what knowledge, teams explore further to get more process knowledge with data collection, analysis and discussions during the subsequent phases of DMAIC.

Knowing-what is knowledge about the state of the world and dealing with facts and concepts. Knowing-how is the competence knowledge that deals with skills, procedures and processes (Kogut and Zander, 1992). Knowing-what is what Deming calls science of the process, the process task knowledge, and knowing-how is Deming's profound knowledge, a fundamental knowledge that is scientific and contributes to the methodological knowledge necessary for conducting process inquiry that enhances organizational learning (Deming, 1986).

Knowing-how is a broader set of knowledge that the Six Sigma team acquires during the Analyze, Improve and Control phases of DMAIC. The researcher defines this learning behaviour or capability as a collective learning behaviour of the team in knowing and implementing far-reaching adaptations, including modification of processes for improved outcome. Thus, it includes both the learning behaviour and the knowledge created by the team. Various activities the team undertakes, along with the outcome and overall effects of those activities and the key references are displayed in Table 3.4

Table 3.3 Knowing-what activities and outcome

Activities	Outcome	Overall effects	References
Seek information from customers and suppliers	Know more about the process, incoming variations and quality requirements of the product/services coming out of the processes	Problem-solving skills improved; more knowledge of the process under investigation	Zu et al. (2008); Chakravorty (2009); Anand et al.(2010); Arumugam (2011); Linderman et al.(2010); Breyfogle (1999); Voelpel et al.(2005); Nair et al. (2011); Gutiérrez et al. (2011).
Talk to people with similar project experience	Gain project experiences and learns what works well for projects		
Study similar projects	Gain more knowledge on the problem- solving approach and use of tools and techniques		
Seek information/knowledge from outside experts (internal and external to the organization), get convincing narratives and histories	Get more process knowledge from success stories and learn from mistakes		

Table 3.4 Knowing-how activities and outcome

Activities	Outcome	Overall effects	References
Carry out critical observation	Gain more insight and understanding of the process	Creation of team level knowledge of the process; Enhanced process capability and improved quality of product/service; Increased team capability; Improved organizational learning.	Pande et al.(2002); Arumugam et al.(2011); Anand et al. (2010); Harry and Schroeder (2000); Breyfogle (1999); Evans and Lindsay (2005); Evans and Lindsay (2005); Henderson and Evans (2000); Brun (2011); Hoerl (2001); Chakravorty (2009); Bohn (1994); Edmondson (1999); Nadler et al. (2003); Nair et al. (2011).
Use statistical tools to analyze data and use scientific principles to understand process behaviour and relationships among variables	Deduce causal relationships of all variables		
Discuss and brainstorm to gain more understanding	Synthesize individual knowledge into team-level knowledge		
Reflection and action cycle	Identify improved combinations of variables for enhanced output and implement changes		

3.7.3 Hypotheses: Technical and Psychological factors and their impact on learning behaviours

This section develops five testable hypotheses. The first hypothesis connects knowing-what and knowing-how to project performance. The next two hypotheses are related to six sigma resources (technical factor), team psychological safety (psychological factor) and learning behaviours. The last two hypotheses link the structured method and leader behaviour to the two learning behaviours.

Research shows that team-learning activities mediate the relationship between team inputs, such as composition, structure, and context, and team outputs, such as innovation, efficiency, and quality (Edmondson et al., 2007). Scholars focus on learning activities in terms of learning behaviours or mechanisms adopted by the team members, and investigate how various organizational antecedents affect them. Table 3.2 (in chapter 3) displays recent studies with the main findings, which reveal that team structure such as, team contexts and leader behaviour, and shared beliefs, such as, team psychological safety shape team outcomes through learning behaviours.

Quality management literature suggests that a very few studies have focused on influencing variables and their effects on learning and knowledge creation in Six Sigma project teams (Gutiérrez et al., 2011; Linderman et al., 2010) and, in turn, project performance (Choo et al., 2007; Lloréns and Molina, 2006). This is surprising since scholars have noted technical and social components of quality/process management lead to learning and knowledge creation (Hackman and Wageman, 1995; Wruck and Jensen, 1994), and organizational factors, such as managerial actions, and contextual factors, such as team composition, task conditions, learning goals, leader behavior and socialization, influence learning in teams (Cohen and Levinthal, 1990; Van den Bosch et al., 1998; Edmondson, 1999).

Scholars have noted technical and social components of quality/process management lead to learning and knowledge creation (Hackman and Wageman, 1995; Wruck and Jensen, 1994). But only a very few studies have focused the impact of technical and social factors on learning and knowledge creation in quality improvement projects. The implementation of Six Sigma requires both technical and process perspectives (Macadam and Lafferty, 2004; Choo et al., 2007a). This section develops two hypotheses to investigate the effects of the following technical and social factors on the two learning behaviours and project performance.

(1) Six Sigma resources (technical), an organizational level factor

(2) Team psychological safety (social), a project level factor

By doing so, this study empirically supports the earlier research of Linderman et al. (2010), and Lloréns and Molina (2006), and extends the research by Choo et al. (2007b).

Project resources

An important influencing factor in Six Sigma project teams is the project resources provided by the management, a distinct characteristic of Six Sigma projects that differentiate Six Sigma project execution from other projects. Unlike other project teams such as, new product development teams, information technology development, and implementation project team, in Six Sigma, specialized and dedicated resources are provided for project execution. The Six Sigma resources include exclusive Six Sigma specialists who are trained in Six Sigma methods and tools to lead projects, information technology support through Six Sigma information systems where project details are documented for tracking and monitoring, statistical software for data analysis, and continued support by top management teams in executing projects (Antony et al., 2007b; Antony and Banuelas, 2002; Linderman et al., 2010; Pande et al., 2000; Pyzdek, 2003; Schroeder et al., 2008). This study investigates the impact of the project resource which is an organizational factor of Six Sigma.

Team psychological safety

There is increasing evidence that social interactions influence the knowledge process in organizations (Brown and Duguid, 1991; Garvin, 1993; Nonaka, 1994; Weick, 1979; Yanow, 2000). Nonaka (1994) emphasizes the importance of socialization where team members create new ideas through dialogue. Socialization capabilities are related to organizational psychology (Bartlett and Ghoshal, 1989). If a conducive and comfortable team climate characterized by interpersonal trust and mutual respect in which people are comfortable being themselves exists, team members feel psychologically safe. This sense of safety, called "team psychological safety" (Edmondson, 1999), is defined as a shared belief that the team is safe for interpersonal risk taking. When such an environment is present in the team, each team member feels a sense of confidence and he or she feels the team will not embarrass, reject or punish him or her for speaking up (Kahn, 1990; Edmondson, 1999). This psychological experience shapes the processes of people engaging in knowledge transfer among the team members (Edmondson, 1999; Tucker et al., 2007). In such environments, members show interest in exchanging knowledge with fellow team members, and this enhances the conversion of individual knowledge into team-level knowledge. Thus, team psychological safety influences team learning behaviours. There is increasing evidence in team learning literature that psychological safety affects learning behaviour positively (Edmondson, 1999; Choo et al., 2007). This study, therefore, investigates the impact of psychological safety in Six Sigma project team's learning behaviours.

Earlier research by Kahn (1990) has shown that the relationship between people representing different hierarchical echelons is potentially more stifling and threatening than relations with peers (Kahn, 1990). In Six Sigma project team, members are trained in tools and techniques in problem solving. Moreover, each individual participating in the project is an expert in his field/function and hence they will have more confidence. Prior research has shown that the higher the confidence, the higher will be the motivation to share their knowledge, but at a higher level of confidence, psychological safety will have a lower effect on motivation (Siemsen et al., 2009). Therefore, learning behaviour of the individual may not be influenced by psychological safety. However, knowledge sharing and the consequent new team level knowledge creation that may take place in meetings, including discussions or brainstorming sessions are likely to be influenced by psychological safety. To sum up, the effect of psychological safety on learning and knowledge transfer in a Six Sigma team may differ from other teams.

Project performance

Each Six Sigma project team will have a different project goal, such as cost reduction, process cycle time reduction, efficiency increase, productivity increase, project capability enhancement (from a low to a higher sigma level), and rejection level reduction. Customer satisfaction, cost benefit and strategic importance are the beneficial objectives of six sigma deployment (Pande et al, 2000; Schroeder et al., 2008), and hence projects should focus on one or more of these objectives. In general, the projects aim for customer satisfaction in terms of cost and quality, cost benefit to the organization in terms of cost savings, and an impact on the strategic objective of the organization (Pande et al., 2000; Schroeder et al., 2008; Antony and Banuelas, 2002). By improving the process capability, teams try to achieve improved quality, enhanced productivity leading to cost reduction and customer satisfaction.

3.7.3.1 Knowing-what, knowing-how and project performance

Knowing-how is effective if the team is capable of carrying out the project beyond the Measure phase, having acquired an essential knowledge of the process and attained skills in problem-solving through knowing-what learning. Thus, knowing-what which refers to the knowledge brought through Define and Measure phase (exploitative) affects the project outcome through knowing-how which is the knowledge gathered through the subsequent phases-Analyze and Improve (explorative) -of the project. This implies that the knowing-how mediates the relationship between knowing-what and performance (Baron and Kenny, 1986). Mediation refers to an indirect effect of knowing-what on performance through knowing-how. As Levinthal and March (1993) argue, organizations need to manage the balance between explorative and exploitative learning. Simultaneous application of these components results in internal innovation (Tushman and O'Reilly, 1996).

Scholars note that shared interpretations of knowledge mediates the effect of knowledge dissemination on the design of process improvement (Huber, 1982; Nonaka and Takeuchi, 1995; Hult et al., 2004), since shared meaning provides a basis for a common and focused effort among organizational members (Weick, 1979; Daft and Weick, 1984). Research suggests that shared interpretation of knowledge among operational personnel mediates how knowledge is disseminated and used to design and implement a unified operational response to that knowledge (Fugate et al., 2009). It implies that without the effect of knowing-what, knowing-how cannot include full value creation. The reverse is also true, and the complementary nature of the two learning mechanisms is evident. An increase in one knowledge process may not have a positive effect on project performance independent of the other. Based on the arguments above, the impact of knowing-what on knowing-how, knowing-what on performance, and knowing-how on performance should be equally positive. Hence:

> ***H1**: Knowing-how mediates the relationship between knowing-what and project performance.*

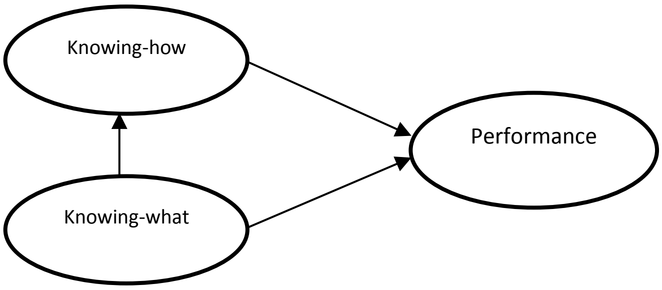


Figure 3.5 Mediation model of knowing-what, knowing-how and performance

Figure 3.5 displays the first research framework, showing how knowing-how mediates the effect of knowing-what on project performance.

3.7.3.2 Six Sigma resources, learning behaviours and performance

Past research has shown that resource is associated positively with learning, innovation and performance (Cohen and Levinthal, 1990; Lawrence and Dyer, 1983). The role-structure in Six Sigma facilitates a hierarchical coordination mechanism of work for quality improvement across multiple organizational levels, ensuring better work design and coordination capability (Sinha and Van de Ven, 2005; Zu et al., 2008; Van den Bosch et al., 1999; Kogut and Zander, 1992). This infrastructure provides an organizational context that enables and ensures the organization towards systematically improving processes (Anand et al., 2009). On the other hand, lack of coordination and support result in slow progress, and subsequently lead to project failure (Choo et al., 2007; Wruck and Jensen, 1998). Past research into Six Sigma context has shown that the coaching expertise of Black Belts is positively related to the project performance (Hagen, 2010; Arumugam, 2014).

Research shows that differential training at different levels helps facilitate improved effectiveness in project teams due to knowledge creation (Linderman et al., 2003; Lee and Ebrahimpour, 1985; Lapré and Van Wassenhove (2001). Zu and Fredendall (2009) found that employee involvement, training and performance and recognition have a positive effect on DMAIC. In related research, Zu et al. (2008)

found that the Six Sigma role structure supports DMAIC, adherence to which promotes activities that meet the project goals, especially challenging goals, and help achieve project success (Linderman et al., 2006). Further, past research has shown that the adherence to methods such as DMAIC positively influences learning behaviour in the team (Choo et al., 2007; Anand et al., 2010). Project database helps the team with many suggestions and ideas for successful execution of their projects and thus knowing-what and knowing-how knowledge (Linderman et al., 2010).

Research into the R&D environment shows that the resource, such as facilities, equipment and access to information can enhance creativity (Amabile and Gryskiewicz, 1987) and project success. The aforementioned discussion indicates that resource availability/provision is critical to the success of a Six Sigma project using the DMAIC methodology (i.e. knowing-what in the Define and Measure phases and Knowing-how in the Analyze, Improve and Control phases). Thus, resources are seen as indirectly impacting on performance through learning. Based on these arguments, the effects of resources on both knowing-what and performance should be equally positive. Furthermore, because of H1, which posits that knowing-what has a positive influence on performance through knowing-how, hence,

> ***H2**: Knowing-what and knowing-how mediate the effect of resources on project performance.*

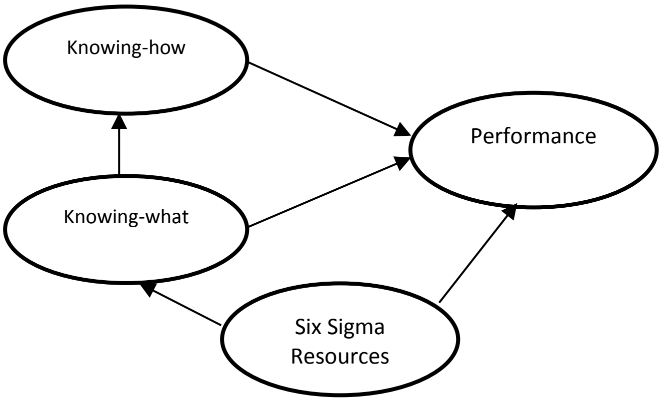


Figure 3.6 Mediation model of Six Sigma resources, knowing-what, knowing-how and performance

3.7.3.3 Psychological safety, learning behaviours and performance

Psychological safety influences the team's cognitive ability to gain more insights and a collective understanding of the problems and issues with the process, enhancing knowledge creation (Choo et al., 2007) and, hence, knowing-how. Past research has shown that team psychological safety has improved team learning behaviour, such as seeking feedback and help and speaking up about mistakes in work teams, and in turn team performance (Edmondson, 1999). In Six Sigma context, Choo et al. (2007) found that psychological safety influences knowledge creation and, in turn, performance in a project team. A recent study by Tucker et al. (2007) undertaken in hospital improvement teams investigated the effect of psychological safety on learn-how activities that operationalize practices. They found that psychological safety enables learn-how, which leads to concrete changes in work practices.

Edmondson (1999) found that learning behaviour mediates the effects of psychological safety on team performance, concluding that team learning behaviour translates effective team design and leadership into team performance. This psychologically safe atmosphere of risk taking encourages exploration and creativity (Amabile et al., 1996); it shows the influence on knowing-how, which we operationalize to represent knowledge creation, innovative solution creation and implementation. We posit that psychological safety affects knowing-how positively and, in turn, project performance. Thus:

> ***H3**: Knowing-how mediates the relationship between psychological safety and project performance.*

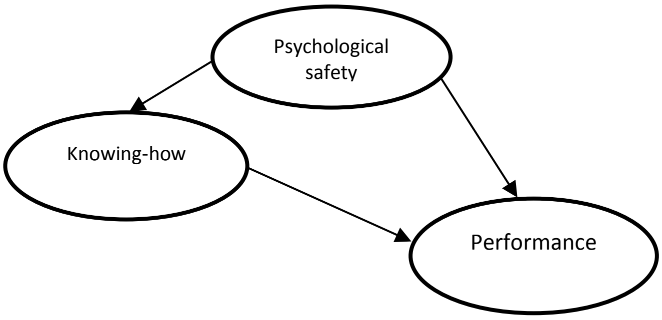


Figure 3.7 Mediation model of psychological safety, knowing-how and performance

3.7.3.4 Method and project leader's behaviour

In teams, leadership role involves managing key tasks and functions essentials for team performance (Mintzberg, 1973). In Six Sigma process improvement teams where knowledge building to solve the problem is an important task, the team leader needs to act as *a knowledge builder*, apart from other usual team tasks such as team building, stakeholder liaison and standard upholding (Bain et al., 2005). Bain and his colleagues identified tasks such as providing advice on technical issues, development of team's expertise, scan the environment for new ideas, monitor the quality of the team's work and initiate new approaches to the team's task that enhances knowledge building in teams (Bain et al., 2005). By these, team leader instigates team discussions and reviews which lead to team knowledge sharing and development of team's expertise that enhance project performance. Prior research has shown that leader facilitates the team to understand the process, to see the problems as opportunities, and to formally challenge the fundamental assumptions until the root causes are identified, characterized, optimized and controlled through DMAIC phases (Arumugam, 2012). As a key interface between team members, these specialist project leaders encourage team learning behaviour of the team during the initial phases of DMAIC to make them reach a collective understanding of the process through data collection and analysis, help team in applying appropriate tools to get insight into the problem (Define, Measure and Analyse phases) and encourage the application of newly gained knowledge during the Improve phase of DMAIC to reach an optimal solution and implementation and finally help team in sustaining the benefits obtained during Control phase (Anand et al., 2010; Arumugam,2012; Breyfoglie, 2003; Choo et al., 2007b; Hoerl, 2001; Linderman et al., 2010; Snee and Hoerl, 2003).

Thus, the success of the project through DMAIC phases is ensured through various actions by project leader. Project leader's role is seen as an intervening mechanism between Method, which is an antecedent and knowing-what and knowing-how which are the consequent variables. Based on the above arguments, we posit that the Method impacts learning behaviours through leader's knowledge building role. Further, both Method and project leader simultaneously impacts learning behaviours. Hence, the following two hypotheses:

> ***H4**: Project leader's knowledge building behaviour partially mediates the relationship between structured method and knowing-what learning behaviour*
>
> ***H5**: Project leader's knowledge building behaviour partially mediates the relationship between structured method and knowing-how learning behaviour*

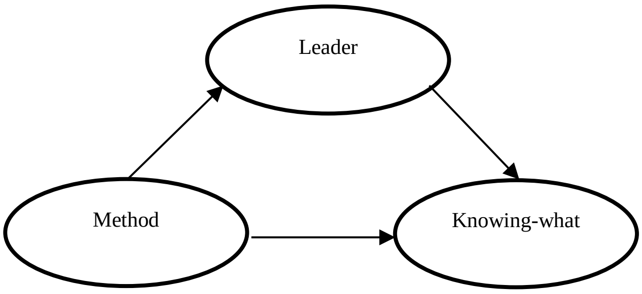


Figure 3.8 Mediation model of method, leader, and knowing-what

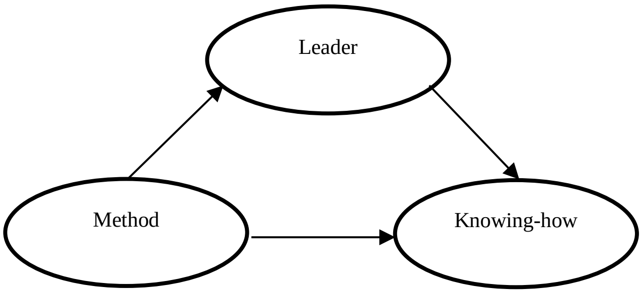


Figure 3.9 Mediation model of method, leader, and knowing-how

3.7.4 Hypotheses: Interactions of the technical and the social aspects on project performance

This section examines how the motivational aspects (social) of challenging goals and technical aspects of projects (method and tools) jointly affect learning and knowledge creation and in turn project performance. In section 2.3.1.3, while discussing various theoretical perspectives that are used in extant literature to explain Six Sigma, it was pointed out that no coherent single theory could offer a valid explanation of the Six Sigma phenomenon. It was suggested by the researcher that the interaction of multiple theories relative to a single theory, integrating managerial actions, and involvement of people in the organizations (behavioural aspects of teams) may provide a coherent theoretical understanding of complex phenomena such as Six Sigma.

In this research, as mentioned earlier, the researcher makes use of well developed theories of other management streams to explain the project success. For the first time in Six Sigma literature, the use of more than one theory to explain a complex phenomenon of project execution-how, technical aspect interacts with social aspects to impact performance through knowledge (knowledge management) - is attempted in this study.

Drawing on the goal-setting theory perspective of Six Sigma, this study examines the hitherto unexplored mediating role of knowledge in the link between challenging goals and project performance in Six Sigma projects. By invoking Sociotechnical Systems (STS) theory, the study investigates how the structured method and tools of Six Sigma might moderate this mediating effect. This theory proposes that joint optimization of the social and technical components of the work systems is considered to be more desirable than simple optimization of either system at the expense of others (Cummings, 1978, Emery and Trist, 1969; Cherns, 1978). The investigation of the research question RQ4 (*H7, H8 and H9)* will be conducted using the STS theory and goal theory.

An emerging stream of research during the past few years has aimed to understand Six Sigma by drawing on management and behavioural theories. Employing goal-setting theory (Locke & Latham, 1990), Linderman et al. (2003)

have proposed a goal-theoretic model of Six Sigma and argue that specific and challenging Six Sigma goals lead to more effort, persistence and direction by team members than vague goals, and goals can be effective when project teams adhere to Six Sigma tools and methods.

Most recent research on work motivation has established that goals have a consistent direct relationship with learning and performance (Kozlowski et al., 2001). The creativity literature is also of the view that when people are given challenging problems, they tend to be more creative, leading to more knowledge creation (Amabile, Conti, Coon, Lazenby, & Herron, 1996; Amabile & Gryskiewicz, 1987). Challenging goals help teams stimulate new ideas and intuitions (Choo et al., 2007b) as reflected in a recent study by Choo (2011), which finds that the sense of challenge in Six Sigma project teams impacts knowledge creation. However, Choo's (2011) study did not investigate performance consequences. In this study, the researcher incorporates knowledge into the goal-theoretic perspective of Six Sigma and examines how the goal–performance relationship in Six Sigma project teams might be mediated by the knowledge created, which has not yet been explored in the literature. Knowledge creation provides an appropriate lens through which to study Six Sigma projects (Anand et al., 2010). The first objective, therefore, is to develop this possibility theoretically and empirically examine it.

As the interaction between context and action influences organizational effectiveness (Ghoshal & Bartlett, 1994), several scholars have recommended a more contingent approach to the study of projects, which may help new insights emerge (Eisenhardt & Tabrizi, 1995). Six Sigma project teams follow a structured method – define, measure, analyze, improve and control (DMAIC) – with embedded tools and techniques. This structured method and its tools (hereinafter "method"), being a systematic approach to problem solving, mobilizes all the efforts of team members towards project execution and thus supports the control of work behaviour (Lawrence & Phillips, 1998). It is likely that the method, with its various embedded mechanisms such as planning, monitoring, attention and tracking, and time management, plays a role in regulating learning in teams. The relative importance of the method and challenging goals for learning and knowledge–and in turn for project performance – has not been examined directly in the prior literature. Our second objective, therefore, is to investigate how the method moderates our hypothesized "goal–knowledge–performance" relationship.

The applicability of sociotechnical systems (STS) theory in relation to Six Sigma has been recognized widely by operations management scholars (Kull, Narasimhan, & Schroeder, 2012; Linderman et al., 2010). The STS perspective advocates a clear linkage between the technical system and social system to enhance organizational effectiveness (Pasmore, 1988; Trist & Bamforth, 1951). The STS theory is invoked in this research, as it provides an explanatory background for how a structured method (technical) and the motivational effect of challenging goals (social) interact to exert an impact on project performance through knowledge creation. This *mediated moderation* relationship is investigated using a robust analytical method incorporating both regression and path analysis as proposed by Edwards and Lambert (2007). By using this analytical approach, the study assesses the direct, indirect and total effects of goals on project performance at low and high levels of method implementation. This study shows that the Six Sigma method and challenging goals are related in interesting ways and offers new insights into the differential impact of these two important factors on Six Sigma project performance. The findings advance our understanding of the theory underlying the goal–performance relationship in Six Sigma projects.

3.7.4.1 Six Sigma projects, challenging goals and method/tools

Six Sigma project team members are drawn from different and diverse functions that are related to the process being improved and they typically work on a part-time basis, whereas the project leader, who is trained and certified in Six Sigma methodology, works full time. The members collaborate temporarily and work intensively to achieve a common goal over limited time duration (Antony, 2004; Pande et al., 2000). Having a cross-functional team increases the chances of team members learning from each other and increases the total pool of knowledge and skills available for team performance (Arumugam et al., 2013; Lloréns-Montes & Molina, 2006). The structured method of Six Sigma provides a systematic and rational way to solve problems and thus promotes rational decision making (Cyert & March, 1963; Daft, 2000), which makes the search for solutions more effective and efficient than it would be otherwise (Choo et al., 2007a).

Six Sigma projects are identified and selected based on certain criteria, such as cost saving and customer satisfaction, and are linked to the business strategy and organizational goals (Antony, 2004; Harry & Schroeder, 2000; Pande et al., 2000). Six Sigma projects start by defining what needs to be improved in the product or service in the "define" phase of the DMAIC method. Improvement goals are then set based on the baseline performance. Six Sigma is known for employing challenging goals, sometimes representing as high as a 10-fold increase from the baseline performance (Harry & Schroeder, 2000; Linderman et al., 2003; Pande et al., 2000), and this challenging goal is far beyond normal quality levels, requiring very aggressive improvement efforts on the part of the project team.

In the "measure" phase, rigorous data collection is done, while, in the "analyze" phase, data analysis is carried out to identify the contributing input factors that influence the project outcome. The team uses statistical techniques for information gathering, analysis, and interpretation. Operational problems are translated into statistical problems and are solved using proven mathematical tools, and the results are translated back to practical actions (Goh & Xie, 2004).

Based on the knowledge gained, the team develops a practicable solution and implements it to improve processes in the "improve" phase of the DMAIC procedure. Finally, in the "control" phase, the team institutes control measures to sustain the benefits obtained. Control measures include setting standards for measuring project performance, putting in place a reaction plan to adjust the process if it deviates from the established norms and setting and documenting procedures for process control. The improved process is then handed over to the process owners (Harry & Schroeder, 2000; Linderman et al., 2010; Pande et al., 2000; Schroeder et al., 2008). By carrying out a series of such projects, organizations systematically change their business processes or routines and achieve improved business performance.

3.7.4.2 Goal-setting theory

Goal-setting theory, which is well developed in the behavioural literature, states that specific difficult goals yield higher performance than nonspecific (do your best) goals and that specific difficult goals yield higher performance than specific easy goals (Locke & Latham, 1990, 2002). Goals serve as a motivational mechanism that regulates human action (Locke et al., 1981). Challenging goals mobilize effort, direct attention, encourage persistence and influence strategy development (Locke & Latham, 1990; Seijts & Latham, 2005). These mediators are well documented in the behavioural and applied industrial psychology literature (see Locke & Latham, 1990, 2002 for a thorough review). Goal theory also applies to team goals (Kleingeld et al. 2011; O'Leary-Kelly et al. 1994; Locke & Latham, 2002; Weldon & Weingart, 1993).

Drawing on goal-setting theory, Linderman et al. (2003) propose the goal theory perspective to afford a better understanding of Six Sigma. They argue that a clear and challenging goal, which is the centerpiece of Six Sigma, results in more team member effort, persistence and focus on activities to accomplish improvement activities leading to a higher magnitude of performance. An explicit challenging goal is set in the early phase of the execution of Six Sigma projects, which generates momentum within the team, motivating team members to make a commitment to the project and develop strategies for its success. Extensive training on the DMAIC method and problem-solving tools provided to project teams enhances their ability to solve challenging problems. Furthermore, the involvement of the senior management team in project selection and prioritization, together with the continual support extended to the project team by the senior management team, increases goal commitment on the part of the team and thus enhances performance (Linderman et al., 2003). Gutiérrez, Lloréns-Montes, and Sanchez (2009) argue that the challenging goals help establish better orientation among team members towards a shared vision that in turn helps teams achieve project success. Overall, goals trigger motivational mechanisms, such as planning, cooperation, morale-building communication and collective efficacy (Weldon & Weingart, 1993). Linderman et al. (2006) have empirically verified that the degree to which teams adhere to the use of tools and the method positively moderates the effect of challenging goals on project performance.

3.7.4.3 Sociotechnical systems (STS) theory

Sociotechnical systems (STS) theory provides a descriptive framework for understanding relationships between social and technical systems within organizations. The STS perspective advocates a clear linkage between technical and social systems to enable enhanced organizational effectiveness (Pasmore, 1988; Trist

& Bamforth, 1951). STS theory proposes that joint optimization of the social and technical components of work systems is considered more desirable than a mere optimization of either system at the expense of others (Cherns, 1987; Cummings, 1978; Emery & Trist, 1969). The technical system of an organization refers to tools, techniques, artifacts, methods, configurations and procedures that are used by organizations to acquire and transform input into output to customers; the social system is comprised of the people who work in the organization and all that is human about their presence (Pasmore, 1988). Therefore, from an STS perspective, the method used by Six Sigma teams to carry out projects is part of the technical system, whereas the goals that motivate team members towards achieving the task are part of the social system.

STS theory acknowledges that social values play a significant role in human decisions and behaviour (Cherns, 1987) and a change in the technical system would affect the social system and vice versa (Pasmore, 1988). STS theory emphasizes that social systems will influence technical systems in enhancing organizational outcomes (Fox, 1995). The STS perspective also explicitly recognizes the authority of teams to alter work methods to develop enhanced performance (Emery & Thorsrud, 1976; Trist, 1978). These aspects of STS theory are especially useful in developing hypotheses to investigate how challenging goals relate to the Six Sigma method to influence project performance.

3.7.4.4 Hypotheses

Drawing on the goal theory perspective, Linderman et al. (2006) have proposed and established that the method moderates the effect of challenging goals for project performance. Choo's (2011) investigation found empirical support for the influence of challenging goals on knowledge creation. Building on their findings, we develop our research model. Using this model, we investigate the relative importance of challenging goals and the method and estimate the extent to which the method influences the direct and indirect effects of challenging goals on project performance transmitted through the knowledge created.

Locke et al. (1981) argue that hard goals may only improve performance if they lead to useful strategies. Strategy refers to action plans for attaining goals, and an action plan involves skills development or creative problem-solving in teams. Skills development results partly from experiential learning, such as on-the-job activities and action learning, and partly through interactions with others and training, which involve learning and knowledge creation (Argote et al., 2003). Creative problem solving also involves learning and knowledge creation (Amabile, 1996; Amabile, Conti, Coon, Lazenby, & Herron, 1996) as acquiring new knowledge is the primary source for innovation (Nonaka & Takeuchi, 1995; Teece, Pisano, & Shuen, 1997). Furthermore, challenging goals can prompt exploratory learning through experimentation, innovation and broad searching as organizational actors seek new or varied approaches to reach the target identified (Sitkin et al., 2011).

Locke & Latham (1990) assert that goals activate the knowledge and skills an individual possesses that are perceived to be relevant to the task. This motivates team members to learn from each other and facilitates knowledge sharing among them. In addition, functional diversity facilitates the flow of information and knowledge. Motivation for learning that is induced by a challenging goal is a form of self-regulated learning. Self-regulated learning is the amalgamation of affective, cognitive and behavioural processes that aims to attain a desired goal (Sitzmann & Ely, 2011). Information exchanges between team members, stimulate them to think about their performance, which in turn helps them search for ways to perform better (Earley, Northcraft, Lee, & Lituchy, 1990). The team acquires knowledge about the process under investigation, deduces unknown consequences and comes to a broad and collective understanding of the process and various influencing factors that affect process output (Arumugam et al., 2013).

There is increasing evidence that new knowledge has a positive relationship with performance and productivity (Davenport & Prusak, 2000). Knowledge enhances improved decision making (Mukherjee et al.., 1998), better problem solving (Kogut & Zander, 1992) and enhanced creativity (Davenport & Prusak, 2000; Nonaka & Takeuchi, 1995; Teece, Pisano, & Shuen, 1997). Using new-found knowledge, therefore, the Six Sigma team can generate operational solutions and implements them to improve performance. Based on the above arguments, we can expect that challenging goals influence performance through knowledge creation in project teams. The first hypothesis is thus:

H6*: Challenging goals have an impact on project performance through knowledge in Six Sigma project teams*

A challenging goal requires a quantum leap from the current level of performance and this calls for an extremely innovative solution, resulting in an extremely capable process with a higher sigma level (Harry & Schroeder, 2000; Linderman et al., 2006). The usual way of conducting a project may not be sufficient to identify a high impact solution; rather, it needs radically new approaches in tackling the project. The team needs to think and act “outside the box” and follow unstructured ways of carrying out projects, exploring new ways of doing tasks to attain an exponential rate of improvement. The team should be open to new information from a variety of sources (Huber, 1991) and requires flexible thinking concerning alternative strategies for goal attainment (March, 1991; March & Olsen, 1976). The structured method of Six Sigma, on the other hand, provides a systematic and rational way to solve problems and promotes rational decision-making (Cyert & March, 1963; Daft, 2000). A structured method with logical steps, for example, forces team members undertake searches routinely for a solution (Choo et al., 2007b; Linderman et al., 2010). However, according to the creativity literature, a structure such as one comprising methodological elements can be an impediment to creativity (Amabile et al., 1996; Ekvall, 1997). It is likely, therefore, that a strict adherence to the method could adversely impact the effect of challenging goals on project performance. In contrast, if the degree of adherence to the method is low, challenging goals should have more impact on performance. The Six Sigma method, for example, being systematic, structured and rigid in its approach, is likely to be perceived by the teams as controlling.

Given that motivation through social aspects such as goal setting is enduring (Boiral, 2003) and challenging goals can make individuals stretch their standards and expectations (Ghoshal & Bartlett, 1994), we can expect that teams will decide not to adhere strictly to the method. The performance effect of challenging goals becomes more influential while the performance effect of the method diminishes. In addition, taking the STS perspective, which emphasizes and recognizes the authority of teams to alter their work methods to improve performance (Emery & Thorsrud, 1976; Trist, 1978), we expect that teams will choose not to adhere strictly to the method. Consequently, the second hypothesis is as follows:

> ***H7***: *The lower the degree of adherence to the method, the greater the effect of challenging goals on performance*

In the "improve" phase, based on the new-found knowledge, teams generate solutions and select a suitable improvement solution that optimizes the process output. The improvement may involve changes to the process parameters or to the procedures to be followed by the operating people (Arumugam et al., 2013). Advanced tools, such as Design of Experiments (DOE) and failure mode and effect analysis (FMEA), help teams to optimize the process parameters of complex processes (Hoerl, 2001). Choo et al. (2007a) argue that tools provide hard evidence of the efficacy of the proposed changes or modifications to the process, which increases management buy-in. This also helps achieve consensus on proposed solutions in a logical manner, leading to greater acceptance by stakeholders (Choo et al., 2007a). It can be expected, therefore, that the degree of success in converting the created knowledge into a workable and accepted solution for implementation depends on the level of adherence to the method.

While identifying solutions is purely an internal phenomenon within the control of a project team, implementation of the final recommended solution is necessarily influenced by factors such as management and operating people who are external to the project team. This follows from the STS perspective, which assumes that organizations are open systems that depend on the external environment (Pasmore et al., 1982). Thus, these external factors are more influential during the "implementation" phase. Implementation of any changes, for example, requires user support, monitoring and continuous evaluation and acceptance from the users. Teams may often face difficulties in this, as operating people may generally be comfortable with the status quo and question the merits of the new or modified solution as evidenced in the study by Repenning and Sterman (2002) on process improvement efforts. Unlike other projects, in which less significance is placed on the role of the project team in terms of the realization of the benefits of projects once handed over to the client (Muns & Bjeirmi, 1996), in Six Sigma projects, a project team has to ensure that the benefits are realized and that control measures are developed and implemented to sustain the benefits of the projects during the “control” phase prior to handover (Arumugam et al., 2013; Harry & Schroeder, 2000; Linderman et al., 2010; Pande et al., 2000; Schroeder et al., 2008). This requires some amount of trial-and-error experimentation before the modified process is put into regular operation and demands coordinated work within the team, as well as close co-operation between the project team on the one hand and the operating people on the other (Cooke-Davis, 2002). Without coordinated action, trial-and-error experimentation is less likely to yield meaningful results (Huber, 1991; Sitkin et al., 1994). The method can facilitate this coordinated work among team members as members are drawn from various functions that are interfaces for the very problem they are trying to solve. Cross-functional cooperation also helps remove intra-organizational barriers to speed information flow, remove process waste and enhance productivity (Song, Montoya Weiss, & Schmidt, 1997). This coordinating capability can help teams achieve overall group performance (Sinha & Van de Ven, 2005; Van den Bosch et al., 1999).

Thus, we expect a positive interaction effect from adherence to the method on the impact of knowledge on performance. Again, drawing on the STS perspective, we can expect that teams might choose a high degree of adherence to the method in converting knowledge into solution implementation as teams can perceive that a higher level adherence will result in a higher level of performance. The next hypothesis is, therefore, as follows:

> ***H8:*** *The higher the adherence to the method, the greater the effect of knowledge on project performance*

Figure 3.10 shows the hypothesized mediated moderation model. The model specifies that knowledge mediates the effect of challenging goals on performance and the method moderates both the goal–performance (direct effect) and the knowledge–performance paths (second stage indirect effect). Overall, the model signifies that the strength of the goal–knowledge–performance relationship is dependent on the degree of adherence to the method.

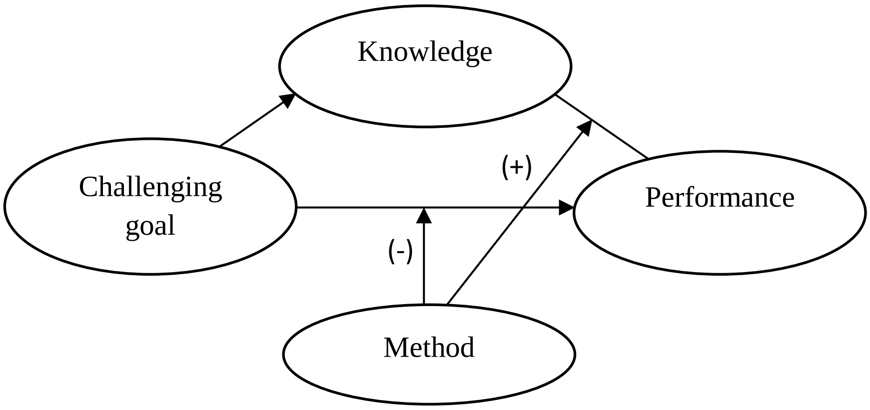


Figure 3.10 Mediated moderation model

3.7.4.5 Summary of chapter 3

Based on a focused review of the Six Sigma literature and team learning literature, this chapter identified the research gap and four research questions (*RQ1-RQ4*). From the conceptual framework developed, the researcher selected four critical managerial factors (resources, psychological safety, project leader, and structured method) with potential influencing effect on learning and developed five hypotheses linking these factors and learning behaviours and project performance (*H1-H5*) relating to *RQ1*, *RQ2* and *RQ3*. Drawing on Goal theory perspective of Six Sigma and Sociotechnical Systems (STS) theory, the researcher developed three hypotheses (*H6-H8*) to investigate how the technical and the social aspects of projects interact to impact project performance through knowledge (*RQ4*). The following chapters will deal with empirical investigation through an appropriate research design and investigate these hypotheses to understand the practice of learning and knowledge creation in Six Sigma project teams, and their antecedents and performance consequences.

CHAPTER 4

RESEARCH PROCESS AND RESEARCH PARADIGM

This chapter gives an introduction and an overview of the research process, followed by discussion on research purpose, research paradigm, and research approaches. The chapter discusses how research paradigm influences the selection of a suitable research design. And aims to identify the nature of the research (descriptive, explanatory, exploratory), philosophical stance (positivist vs. phenomenology) of the researcher, and the methodology (inductive vs. deductive) used for the research.

4.1 Management Research Process

Research process consists of a series of actions or steps that are necessary to carry out research effectively. Figure 4.1 illustrates the sequence of steps involved in the research process (Saunders et al., 2007) and it displays chapters where these steps are explained in the dissertation.

Formulating and clarifying the research topic is the starting point for any research project. The researcher must be clear in his mind why is his study worth doing? What issues does he want it to clarify and what practices and policies does he want it to influence? Why does he wish to conduct this study, and why should others care about the results? (Maxwell, 2013). All these provide motivation for the research. Research problem along with the research objectives justifies the study. The selection of the topic/phenomenon to be studied may be of researcher’s own interest or of the public/organization’s interest; the topic may be related to any pressing problem needing immediate solutions or a phenomenon of interest needing an understanding. Research topic must be something that the researcher is capable of undertaking and must excite the researcher’s imagination (Saunders et al., 2007). A research topic is different from a research problem – the former is broader and more general, whereas a research problem is more specific to the research context. Research problems lead to research questions. Critical review of the literature helps identify what is already known about the subject of interest. The literature review provides a researcher with a basic understanding of how the topic has developed over time and what remains to be investigated. This leads to a series of research questions that his research must answer and objectives his research must address. Research needs to be thorough with the existing theories and research in the field, and hence the researchers must be in touch with a range of perspectives and sources. The review must also be continued throughout the project, and research needs to reflect the new and emerging findings. The following are to be considered while reviewing the literature (Silverman, 2000: 2027).

- What do we already know about the topic?
- What do you have to say about what is already known?
- Has anyone else ever done anything exactly the same as what is proposed?
- Has anyone else done anything that is related?
- Where does the present work fit in what have gone before?
- Why is your research worth doing in the light of what has already been done?

A good review will ensure that the research fits in with the existing wider research within the focal area (Easterby-Smith et al., 2012). A well-executed review will provide the researcher with the knowledge of what we already know about the subject. A clear research question is a point of departure for further research activities (Ghauri and Grønhaug, 2002). However, it is to be noted that the researcher continues to reflect on these and he may revise his ideas and the way he intends to pursue the research, which involve, quite often, revisiting various stages of his research (questions, and objectives) and working through them again (Saunders et al., 2007).

The research topic and research purpose of the present research were discussed in chapter 1. The research hypotheses for the research were developed based on a systematic and focused review of the literature in Chapter 2 and Chapter 3. Chapter 5 discusses the research design; chapters 6, 7 and 8 discuss data collection and analysis, followed by discussions and conclusion in chapter 9.

4.2 Research purpose and research questions

The researcher must be clear about his research purpose and research questions before developing a research design (de Vaus, 2005:17). The researcher should be clear in his intent or purpose to conduct the research. Marshall and Rossman (1999) suggest that the statement of purpose of the research conveys to the researcher what the result of the research was likely to accomplish (Marshall and Rossman, 1999:33).

Accordingly, research purpose could be descriptive, exploratory or explanatory. Table 4.1 displays the relationship between research purpose and research questions.

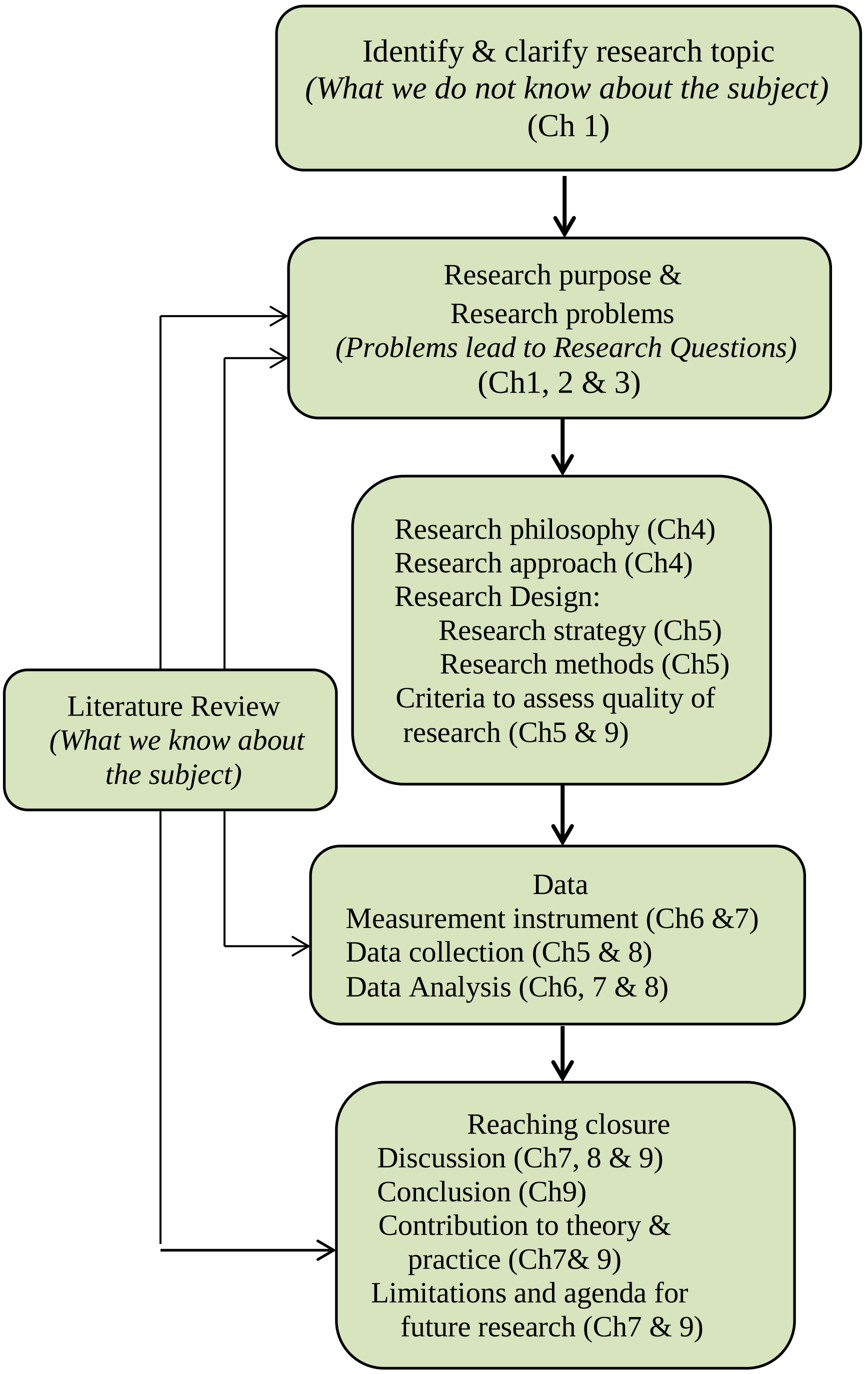


Figure 4.1 Research Process (Adapted from Ghauri and Grønhaug (2002); Saunders et al., 2007; Kumar, 2010)

The purpose of a research may be to describe (discover), explore (understand), or explain (develop) a phenomenon. Descriptive research is undertaken to produce an accurate representation of persons, events, or situations (Saunders et al., 2007). It emphasizes on reporting and recording elements of situations and events (Meredith et al., 1989).

Table 4.1 Research questions and Research purpose

Research purpose	**Research questions**
Descriptive	
To document and describe the phenomenon of interest	What are the salient actions, events, beliefs, attitudes, and social structures and processes occurring in this phenomenon?
The researcher has no control over the variables constituting the phenomenon	
Exploratory	
To investigate less-understood phenomenon and to discover important categories of meaning	What are the salient themes, patterns, or categories of meaning for the participants?
To generate hypotheses for further research	How are these patterns linked with one another?
The researcher tries to find out what is happening, seek insights, ask questions to assess the phenomenon in a new light	
Explanatory	
To explain the patterns related to the phenomenon	What events, beliefs, attitudes, or policies shape this phenomenon?
To identify plausible relationships between variables	How do these forces interact to result in the phenomenon?
The research focuses on establishing a causal relationship between variables related to the phenomenon under investigation	

Adapted from: Marshall and Rossman, 1999; Saunders et al., 2007

Descriptive research focuses on 'what, who, and where' questions (Yin, 2009). The explanatory research focuses on studying a situation in order to explain the causal Relationship among variables existing within the object of study. The explanatory study focuses on 'how and why' questions (Yin, 2009). An exploratory research aims to seek a new insight into phenomena, ask for more detailed levels of description with respect to the object of study, ask questions and assesses the phenomena in a new light. An exploratory study focuses on 'what' questions (Yin, 2009).

The purpose of the present research is to investigate the learning behaviours of Six Sigma project teams, their antecedents and performance consequences. The research aims to bring together current thinking in the field and carry out an empirical investigation to clarify and explain the patterns related to learning and identify plausible relationships between variables and hence explanatory research. The research was carried using a sequential mixed methods design, an explanatory research by a survey research (quantitative analysis) in the first phase of the research, and a multiple case study research (qualitative data analysis) in the second phase of the research to explain the findings of the survey research. Thus, a triangulation approach was used to answer the four research questions:

RQ1: *What are the different learning behaviours or activities exhibited by the project teams?*

RQ2: *How do the learning behaviours of project teams impact project performance?*

RQ3: *How do managerial factors impact learning behaviours and in turn project performance?*

RQ4: *How do social aspects of the project team (goal) and technical aspects of project execution (method) interact to impact project performance through knowledge creation?*

4.3 Research Paradigm

There are two philosophical assumptions in social science research: the nature of reality (**ontology**) and the nature of knowledge (**epistemology**). Ontology refers to basic assumptions made by the researcher about the nature of reality, and Epistemology refers to assumptions about the best ways of inquiring into the nature of the world. Epistemological issues concern the question of what is regarded as acceptable knowledge in a discipline-whether social world can and should be studied according to the same principles, procedures and ethos as the natural science. Ontological and epistemological issues are related in the sense that the latter concerns how human actors may go inquiring about and making sense of the former. Epistemology and paradigm are used interchangeably by researchers.

4.3.1 Ontology

In ontology, researchers take two extreme positions, **realism** and **relativism**. The traditional position of realism holds that the world is concrete and external and that science can only progress through observations that have a direct correspondence to the phenomena being investigated (Easterby-Smith et al., 2012). Another position in the realism–relativism continuum is **transcendental realism,** which assumes that 'the ultimate objects of scientific inquiry exist and act quite independently of scientists and their activity' (Bhasker, 1989, pp 12). **Internal realism** on the other hand, assumes that there is a single reality, but asserts that it is never possible for scientists to access that reality directly, and it is only possible to gather evidences that support what is going on in fundamental physical processes (Putnam, 1987). Relativism posits that scientific laws are not simply out there to be discovered, but they are created by people. It assumes that different observers may have different viewpoints. Ontology can be *subjective* or *objective* and thus explained as "assumptions that we make the nature of reality" (Easterby-Smith et al., 2012, p. 31). **Objective Ontology** asserts that social phenomena and their meanings have an existence that is independent of social actors. It implies that social phenomena and the categories that we use in everyday discourse have an existence that is independent or separate from actors (Bryman, 2008). Any social or organizational entity is an emergent reality, in a continuous state of construction and reconstruction (Becker, 1982). Proponents of **subjective ontology** assert that the social reality is an ongoing accomplishment of social actors rather than something external to them.

4.3.2 Epistemology

A paradigm is a basic set of beliefs about the world (Denzin and Lincoln, 2000); it is a set of linked assumptions, rules, and perceptions about the world which is shared by a community of Scientists investigating the world (Deshpande, 1983: 101; Gummesson, 2000). The progress of scientific practice is based on people's philosophies and assumptions about the world and the nature of knowledge (Collis and Hussey, 2003). Burrell and Morgan (1979) in Collis and Hussey (2003), suggests three different interpretations of paradigm at three different levels: At the philosophical level, it is used to reflect a basic set of beliefs about the world. At the social level, it is used to provide guidelines to a researcher in pursuing his/her research. At the technical level, it is used to specify the choice of appropriate methods and techniques to answer the research questions or when conducting research

Philosophical level

The understanding and impact of these paradigms or philosophical issues on the quality of research is considered highly relevant and, failure to consider the philosophical issues can seriously affect the quality of management research (Easterby-Smith et al, 2013; Collis and Hussey, 2003; Mendibil, 2003). The philosophical paradigm forms the foundations upon which a research design rests, influencing the scoping of the research goals and questions, data collection and analysis methods, and tests of the quality and validity of the study (Easterby-Smith et al, 2012: 17). Paradigm represents a theoretical framework within which research is conducted (Beech, 2005).

Understanding of philosophical issues can help (Easeterby Smith et al., 2012),

- clarify research designs, considering what kind of evidence is required and how is it to be gathered and interpreted
- recognize which research design will work and which will not
- identify, and even create, design that may be outside his or her experience

Positivism and **social constructionism** (phenomenology/interpretivism) are the two extreme philosophical paradigms which dominate the management field (Easterby-Smith et al, 2012; Maxwell, 2005; Saunders *et al*., 2007; Collis and Hussey, 2003; Gummesson, 2000; Gill and Johnson, 2002). They may be considered as the two extremes of a continuum that shapes the philosophical basis for research activity. They are concerned with the nature of reality and whether there is just one reality, which is logical and independent of the researcher or the reality is subjective and socially constructed. As one moves along the continuum, the characteristics and assumptions of one dimension are gradually relaxed and replaced by those of the other paradigms (Collis and Hussey, 2003).

Philosophical assumption of positivism (Easterby-Smith et al, 2012; Scholarios, 2005):

- Positivism assumes that reality can be objectively observed
- It adopts the philosophical stance of the natural scientist
- The researcher is independent of the phenomena under study
- Independence – the observer is independent of what is being observed
- Value-free and scientific – the choice of subject and method can be made objectively, not based on beliefs or interests
- Hypothetico-deductive – hypothesize a law and deduct what kinds of observations will demonstrate its truth or falsity
- Empirical operationalization – typically quantitative
- Principles of probability
- Reductionism – problems as a whole are better understood if they are reduced into their smallest elements
- Generalization – sufficient samples should be selected in order to generalize to the population; samples depend on the population

The end product of such research can be law-like-generalization similar to those produced by the physical and natural scientists (Remenyi et al., 1998). Thus, positivism is an epistemological position that advocates the application of the methods of the natural sciences to the study of social reality and beyond (Bryman, 2008). The researcher's personality traits, his individual expertise, political views and religious beliefs do not interfere with the research, and he applies only logical reasoning to investigate the research problem.

Social constructionism, on the other hand, assumes that reality is a construct of the observer and is determined by people rather than by objective and external factors. As such the researcher cannot be independent of the phenomena being studied. It is socially constructed and given meaning by people. It is concerned with the question of how individuals make sense of the world around them. Social reality is too complex, especially so in management studies, to use definite laws to theorize social phenomena, in the same way, as the physical science. Business situations are not only complex, but also a function of individuals and circumstances. Social sciences deal with action and behaviour which are generated from within the human mind (Collis and Hussey, 2003; Eisenhardt, 1989; Yin, 2009) and the phenomenologist attempts see things from that person's point of view. Hence, reality is determined by people rather than by objective and external factors.

Positivism is being criticized for being over simplistic approach, but is accepted as the optimal approach to understanding causal relationships between a small numbers of well-defined constructs (Easterby-Smith et al., 2012). Similarly, social constructionism also has received criticism for developing theory that is too specific to individual cases and that it loses all meaning and practical implications. But it is hailed as vital to understanding in-depth relationship and the implications of the phenomenon in particular cases (Easterby-Smith et al, 2012). We cannot think that one is better than the other. The choice depends on the research questions the researcher is seeking to answer. Saunders et al. (2007) are of the view that business research is often a mixture of these two (Saunders et al., 2007). There are many researchers, both in management and social science, who combine methods from both traditions (Easterby-Smith et al., 2012). Researchers also position themselves in intermediate positions between positivism and phenomenology such as Axiomatic (Meredith et al., 1989); Critical theory (Meredith et al., 1989); Relativism (Easterby-Smith et al., 2012); Social Constructivism (Easterby-Smith et al., 2012; Lincoln and Guba, 2000); Interpretivism (Meredith et al., 1989) and Post Positivism (Lincoln and Guba, 2000) to name a few.

The practical reality is that management research rarely falls neatly into any one philosophical domain as discussed in the above sections. Recently, **critical realism** has been adopted by many researchers as it provides a compromise position between the stronger versions of positivism and constructionism (Easterby-Smith et al, 2012). Although very few studies have adopted critical realism in its full sense, many studies draw on its ideas to structure processes of data collection and analysis (Easterby-Smith et al., 2012). The major strong point is that it recognizes the value of using multiple sources of data and perspectives.

Positivism locates causal relationships at the level of events, whereas Critical Realism locates them at the level of the generative mechanism. Critical realism asserts that it is highly plausible that a mechanism will exist, but either a) go unactivated, b) be activated, but not perceived, or c) be activated, but counteracted by other mechanisms, which results in it having unpredictable effects. Thus, the non-realization of a posited mechanism cannot (in contrast to the claim of positivists) be taken to signify its non-existence.

Reality exists independently of us and our knowledge and/or perception of it. In critical realism, reality consists of three different layers: empirical (observable by human beings)-comprises the experiences and perceptions that people have; actual (existing in time and space)-comprises events and actions that take place whether they are observed or detected; and real (transfactual and more enduring than our perception of it)- comprises causal powers and mechanisms that cannot be detected directly, but which have real consequences for people and society (Easterby-Smith et al., 2012). Critical realism recognizes that the researcher is critical of the status quo, and at the same time, explanation can be given in a social context.

Social level

Axiology is a branch of philosophy that studies judgments about 'value' (Saunders et al., 2007), and is concerned with the process of social inquiry. It is greatly influenced by the role played by human actors or researchers in all stages of the research process to provide credibility to the research findings. Values reflect either the personal beliefs or feelings of a researcher (Bryman and Bell, 2007). It is expected that the social scientists be value free and objective in their research, i.e. avoiding intrusion and bias in the course of research. Although these assumptions are commonly found in the natural sciences, they are less convincing in social science research, which are concerned with the activities and behaviour of people (Collis and Hussey, 2003: 48).

Methodological level

Finally, the methodological assumption is concerned with the process of the research (Collis and Hussey, 2003). Methodology is the combination of techniques used to inquire into a specific situation (Easterby-Smith *et* al., 2012; Lincoln and Guba, 2000). It relates to the process of the research (Collis and Hussey, 2003), such as deductive (testing of hypotheses or propositions derived from the theory to predict, explain, and understand the phenomena of interest) or inductive (developing theory based on empirical research) (Easterby-Smith et al., 2012; Lincoln and Guba, 2000).

The deduction is generally used within a positivist paradigm; inductive methodology often starts with data rather than literature and is used within a phenomenological paradigm. The basic ontological, epistemological, axiological, and methodological assumptions underlying the two paradigms (positivist and phenomenological) are presented in Table 4.2.

Table 4.2 Assumptions of the two main paradigms (Adapted from Bryman (2008) and Easterby-Smith et al. (2012)

	Positivist paradigm	**Phenomenology/social constructionism paradigm**
Ontology (Nature of reality)	The reality is external and objective The observer is independent Knowledge is objective and value -free	The reality is socially constructed and subjective The observer is part of what is being observed Knowledge is driven by human interest &individual experience
Epistemology (Relationship of the observer with that observed)	The observer is independent Looks for causality Reduce phenomenon in its simplest form Focus on facts	The observer is part of what is being observed Understands what is happening Search for the totality of the situation Focus on meanings
Axiology (Role of values)	Value-free and unbiased	Value-laden and biased
Methodology (Process of research)	Formulate hypotheses and test them (deduction) Operationalize the concepts and measure them for analysis Generalization leading to an explanation, prediction and understanding	Develop ideas through induction from data Use multiple methods to establish different views of the phenomenon Develop patterns and theories for understanding

Table 4.3
Epistemologies in management research (Adapted from Denzin &Lincoln, 2000; Esterby-Smith et al., 2012; Ates, 2008)

Elements	Positivism	Social constructionism
Truth	Determined through verification of predictions	Depends on who establishes it
Facts	Concrete	Al human creation
Aims	Discovery	Invention
Starting point for research	Formulate explicit hypotheses to guide the research	Meanings/Research questions
Goal of research	Prescriptive, casual, deductive, theory confirming, ungrounded	Descriptive
Directions of research	Measurement and analysis of causal relationships between variables that are generalizable	Development of knowledge-based social experiences such as human ideas, beliefs, perceptions, values, etc.
Design	Survey, experiment	Interviews, observation and participant observation
Methodology	Outcome and verification oriented	Observation and process oriented
Techniques	Measurement	Conversation
Sample size	Large	Very small
Data collection	Structured	Unstructured
Hardware	Questionnaires, statistical software	Tape recorders, interview guides, interview protocol, transcript, visual methods, coding
Types of data	Replicable, discrete, statistical	Information-rich, contextual. Non-statistical, subjective reality
Interview questions	Mainly closed with limited probing	very open
Interactions of interviewer and the phenomenon	Independent and value-free, one- way mirror	Participatory and transformative intellectual
Respondent's perspective	Emphasis on outsider's perspective and being distanced from data	Emphasis on outsider's perspective and being distanced from data
Information per respondent	Varies and depend on specific questions	Extensive
Data analysis	Objective, value-free, statistical methods	Value-loaded, non-statitical
Interpretation	Verification/falsification	Sense-making
Causality	Cause-effect relations	Not addressed
Outcome	Causality	Understanding
Judgment of Research quality	External validity and reliability are critical	Credibility, transferability, dependability, and confirmability

Methods are individual techniques for data collection and analysis (Easterby-Smith et al., 2012). When researchers decide to pursue a specific epistemology, they often resort to methods that are commonly used within that epistemology. Some research methods and techniques are statistical testing, experimental, secondary data analysis, case study, observation, interviews and participation. Methods and techniques used in the research will impact on what the researcher can see and find. Table 4.3 summarizes the main distinctions observed among positivism, and social constructionism regarding the interpretation of the nature of reality and their general approach to conducting management research.

4.3.3 Inductive and Deductive approaches

Researcher is often concerned with relating theory with reality and there are two alternative ways of achieving this in social research: deductive and inductive approach (Ghauri & Grønhaug, 2002; Saunders et al., 2007; Easterby-Smith et al., 2012). In the inductive approach, researcher through some empirical observation and evidence, come to a conclusion on a phenomenon or propose a theory about it based on the evidence collected. The researcher needs to be concerned with the context in which the phenomenon takes place. Inductive research involves qualitative data and uses a variety of methods to collect data in order to establish different views of the phenomenon (Easterby-Smith et al., 2012)

In the deductive approach, researcher, on the basis of existing theory or on the basis of what is known, deduces hypotheses under different contexts/scenario, and subject them to empirical scrutiny. The approach involves, deducing testable propositions (hypotheses) about the relationship between various variables from the theory; expressing the hypotheses in operational terms; carrying out an empirical inquiry to test the hypotheses; and examining the outcome related to the existing theory and verifies or modify the theory. The existing theory helps the researcher in determining what information to be gathered, how to interpret this, and how to relate the end results to the existing theory to arrive at the final conclusion, and to prove or disprove hypotheses, and accepting or rejecting or modifying the existing theory. Thus, the purpose of any research is either to build a new theory or test an existing theory: theory construction and theory verification.

Figure 4.2 displays the relationship between these two approaches. It can be stated that the deductive approach is suitable for research within the positivist paradigm and inductive approach to research within phenomenologist paradigm. One should not think that one approach is better than the other as each one is better for doing different things. The selection of approaches or philosophy depends on the research questions that the researcher seeks to answer.

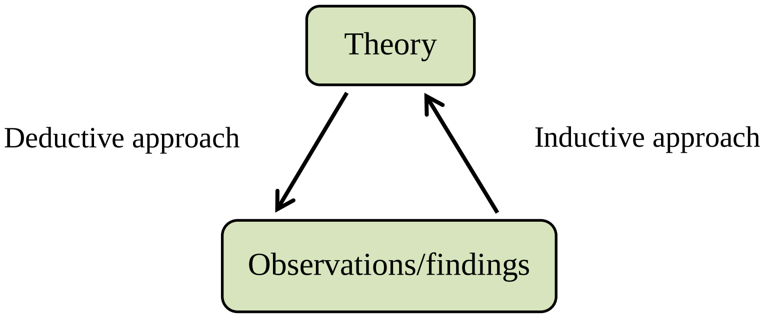


Figure 4.2 Inductive and deductive approaches

Table 4.4 displays the different features of deductive and inductive research approaches.

Table 4.4 Deductive and inductive approaches

Deductive approach	**Inductive approach**
Scientific principles	Understanding of the meaning humans attaches to events
Moving from theory to data	Theory generated from the data
Causal relationship between variables	Understanding of the research context
Quantitative data	Qualitative data
Validity of data need to be ensured	Less concern with the need to generalize
Highly structured approach	Flexibility permitting changes in research emphasis as the research progresses
The researcher is independent of what is being researched	The researcher is part of the research process
The necessity of sufficient samples	

Researchers also combine both inductive and deductive approaches in a single study (Easterby-Smith *et al*., 2012; Yin, 2009; Saunders *et al*., 2007). This *multi-method approach* in a single research has two advantages against using a single approach. First, it mitigates the limitations of the either method. Second, the combined approach can overcome the potential bias and sterility (Collis and Hussey, 2003) and provides more validity and reliability than that of a single approach (Denzin and Lincoln, 2000).

4.4. Implications of Research Philosophy and Research Approach of this study

The researcher is an engineer by profession and became operations manager through his experience. Most of his careers centered within manufacturing, engineering, and continuous improvement and operations. Naturally, he is more conversant with the process-based view, and he approaches management problems through process perspective and goes deep into studying in detail about specific activities and their antecedents and consequences. That could be one of the reasons why he chooses *process based view* as a theoretical framework to investigate learning activities in Six Sigma teams, exploring input, process and output (Chapter 2). Through this research, he seeks to answer how does learning take place (process), what are the antecedents (input), and how are performance consequences affected (relationships with output). A process-based approach enables him to break learning behaviour processes in teams into more specific activities.

Broad research question of this research is ‘‘how does learning take place in Six Sigma project team?’’ and the first specific research question seeks to clarify about the distinct learning behaviours exhibited by team members. The researcher aims to answer this research question through theoretical conceptualization based on the extant research from both Six Sigma and team learning research discipline.

The second research question seeks to answer how learning behaviours affect project performance; and the third and the fourth research questions broadly seek to answer ‘‘how do the organizational and project level factors affect learning behaviours and in turn on project performance?’’ and aim to explain and predict the relationship between factors, learning behaviours and project performance.

4.4.1 Ontology choice for this research: Objective ontology

Easterby-Smith et al. (2002:31) defines *ontology* as the assumptions we make about the reality. Collis and Hussey (2003:48) assert that the researcher must decide whether he/she considers the world as objective and external to the researcher (Objective Ontology) or socially constructed and only understood by examining the human actor's interpretations and perceptions (Subjective Ontology). The researcher believes that the reality exists independently of how he perceives it. He feels more comfortable if the social world is looked at more objectively rather than from the individuals' own perspectives (researcher). Although we may interpret the material world as we wish to, and the interpretations we make might be essential to understanding social phenomena, he believes that the material components of reality as such will not change due to any amount of our own interpretations of them. Hence, he intends to stay independent of the organizations and people and aims to understand their behaviours towards the phenomenon of team learning from outside. Therefore, his preferred ontology is *objective ontology*. His focus is on facts and clarification rather than his meanings. Table 4.5 shows various characteristics of two forms of ontology and how they are applicable to the current research leading to the choice of objective ontology in this research.

Table 4.5 Characteristics of ontology (Beech, 2005)

Relevant Characteristics	Form of Ontology	Applicability	Area relevant to this research
Focus on facts	Objective	Yes	No control is exercised in observing on learning behaviours in teams
Looks for causality	Objective	Yes	The research aims to clarify the linkage between learning behaviours and performance
Reduce phenomenon to its simplest elements	Objective	Yes	Learning behaviours are broken into a series of activities based on the extant literature
Formulate hypotheses and test them	Objective	Yes	A series of hypotheses will be developed and tested subsequently
Operationalize concepts so that they can be measured	Objective	Yes	Concepts are operationalized, measured ,and the collected data is used for testing hypotheses
Take a large sample	Objective	Yes	A large sample data is collected and analyzed
Focus on meanings	Subjective	To some extent	The main objective of the study is to clarify the learning behaviours in teams through survey research. The reality is not going to change considerably in survey research.
Try to understand what is happening	Subjective	To some extent	This research aims to understand team members' language in learning process in teams
Look at the totality of each situation	Subjective	To some extent	The study aims to clarify how learning activities affect the project outcome
Develop ideas through induction from data	Subjective	No	The starting point of the research is extant literature and not data

4.4.2 Epistemology choice and approach for this research

The processes and activities of learning in project teams are seen as independent and objective entities existing in organizations. The researcher aims to clarify learning behaviours in project teams as they are carried out in project teams and he also sees the possibility of investigating the phenomenon so that it can be generalized through a large scale sample study. He prefers the idea of positivism as he recognizes critical of the status quo. Six Sigma project execution, and more specifically the learning in teams are accepted as being a myriad of complex interactions between leadership, teams, culture, interactions, project context, processes, etc. (Choo et al., 2007a;

Linderman et al., 2010). Thus, the phenomenon comprises experiences and perceptions that people in the organization have and comprise causal powers and mechanisms that cannot be detected directly, but real consequences to the organization and people. The consequences, however, will be seen embedded in the organization through routines and practices, which as a researcher he wants to capture. From an epistemological perspective, therefore, the researcher adopts positivist paradigm. The research questions call for theorizing and confirming of one or more aspects of the phenomenon. Hence the research calls for an explanatory study, associating social and technical factors (organizational and project level factors, learning behaviours, project performance) that can provide managers with a solid guidance for explaining and predicting the outcome. This calls for a *positivist* approach. The researcher used deductive approach using survey research in the first phase of the research.

As positivist, the researcher also wants to know the realist view of the world. From an epistemological perspective, therefore, the researcher adopted a triangulation of both phenomenological and positivist paradigm, where both hard and soft data was collected to realize the research aim. In the second phase of research, the researcher adopted a case study research to collect qualitative data to corroborate survey research findings (explanatory sequential research). While undertaking the case studies to collect the data, the researcher was an independent observer and was seeking explanations for various aspects of project execution and learning behaviours in case study projects. The researcher remained as an independent observer throughout the research process. The researcher was in no way trying to influence the result of the study and remained as an independent observer throughout the research process. The researcher adopted a triangulation of both constructionism and positivist paradigm. In the first phase of study, where a survey was conducted, the epistemological stance adopted was positivism, while in the second phase of the study where a case study was conducted, the stance adopted was constructionism. This falls under inductive approach.

The argument against the mixed methods is related to the paradigm. Scholars view and argue that it is unwise to combine different paradigms within the same study (Burrel and Morgan, 1979). Recent thinking about paradigms, however, suggests that the boundaries are more fluid than originally portrayed (Cunliffe, 2011, quoted by Easterby-Smith et al., 2012), and hence it may be acceptable to combine paradigms up to a point. Much of the interest in mixed methods comes from those on the positivist side of the spectrum, who has an internal realist view of the world (Saunders et al., 2007).

During the survey research, the researcher assumed the role of an objective analyst, making independent interpretations and conducting analysis of the data collected in an apparently value-free (axiology) manner (Saunders et al., 2007). The researcher acted as a social constructionist in phase two of the data collection to view the process of understanding the phenomenon as it contributed to the construction of the reality. In this phase of the research, the author takes into account the more sensitive aspects of research and includes value-laden (axiology), rich data (interviews, etc.). As a result, the knowledge that will be generated by this study will be objective and context dependable reality.

The philosophical assumption of the researcher has obvious links to the research methods and techniques adopted for this research and to collect data, which is the topic under discussion in the next chapter.

4.5 Summary of Chapter 4

This chapter discussed various activities that are undertaken in the nine chapters of the dissertation. Understanding the purpose of the research and the nature of research questions facilitated in identifying the nature of the research (explanatory), the philosophical stance (positivist) of the researcher, and the methodology (inductive and deductive) used for the research. The next chapter discusses the research design.

CHAPTER 5

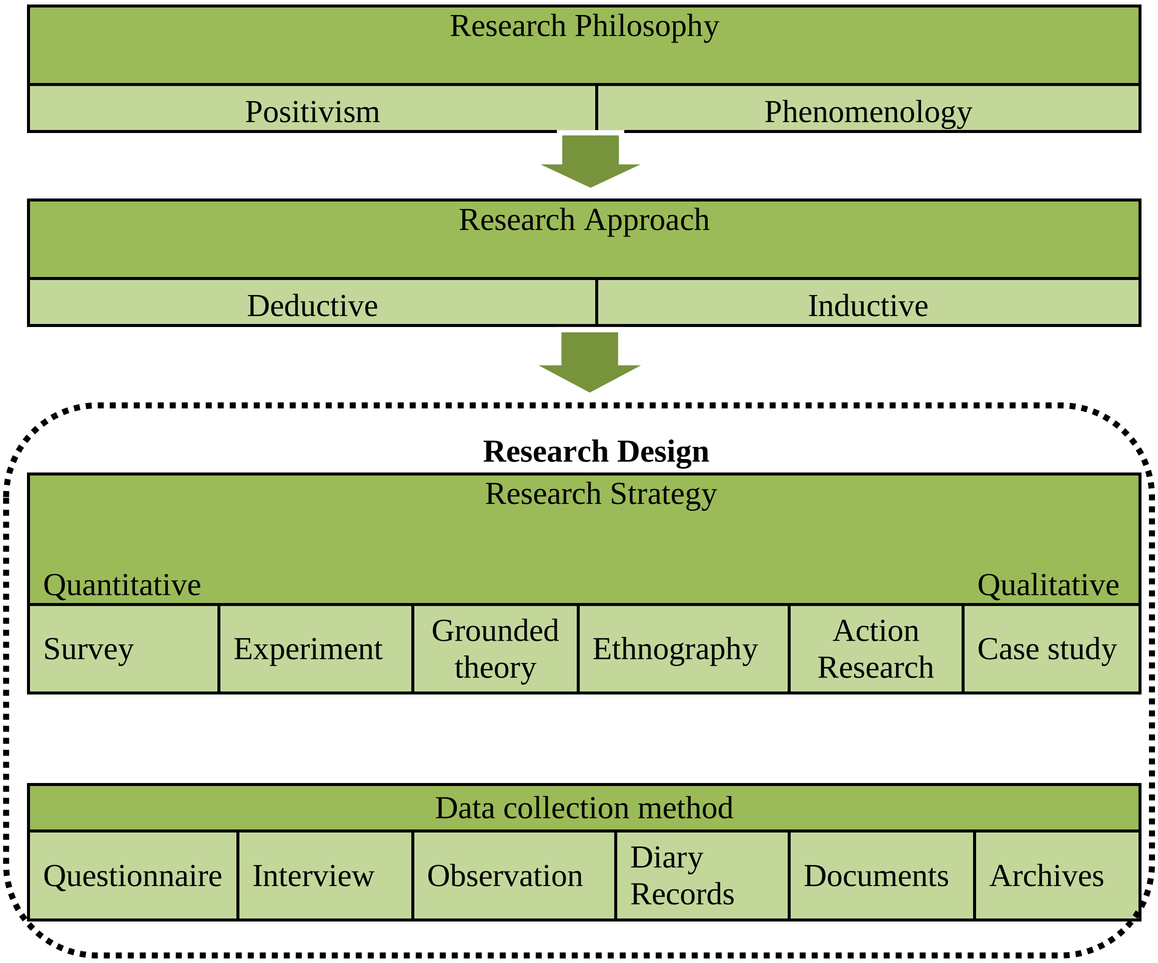
RESEARCH DESIGN

The chapter describes the research design for this research. This chapter outlines the methodology that the researcher will follow and the research strategy with a discussion on the methods employed in conducting the research in order to answer the four research questions developed in chapter 3. The selection of an appropriate strategy and data collection methods for this research are influenced by the research questions and the philosophical paradigms discussed in the previous chapter. The understanding of research design is imperative, as it provides a well thought-out, logical and rational plan to address the research questions. The chapter also includes a discussion on the research quality criteria used to evaluate the overall quality of the research and steps taken by the researcher to ensure the validity of the research

5.1 Research Design

Research design is a conceptual structure within which a research is conducted. It constitutes the blueprint for the collection, measurement and analysis of data (Cooper and Schindler, 2006: 138). ‘‘Research Design is a logical sequence that connects the empirical data to study’s initial research questions and, ultimately, to its conclusion” (Yin, 2009:26). It includes research strategy and research method. Bryman (2008) states that ‘‘a research design provides a framework for the collection and analysis of data’’ (Bryman, 2008: 31). Research design is a blueprint of research dealing with at least four problems: what questions to study; what data are relevant; what data to collect; and how to analyze the results (Philliber et al., 1980). Research design, thus connects the research questions to data collection, measurement, and analysis phase.

A research design reflects the decision of the researcher about the priority being given to various aspects of his research process. Research design includes research strategies and one or two data collection methods, and both of which are influenced by the research questions and philosophical positions underpinning the research. Research strategy is a general plan of how a researcher will go about answering the research questions he has set. It refers to a general orientation to the conduct of business research (Bryman and Bell, 2007:28). At a higher level, research strategy is classified into two: quantitative and qualitative research, and at a lower level, we have a cluster of strategies applicable depending upon the research questions and objective of the research. Commonly used strategies are surveys, experiments, grounded theory, ethnography, action research and case study. They can be placed on a continuum from quantitative to qualitative as shown in Figure 5.1. Research design and research method are sometimes used interchangeably, though there is a significant difference between the two. Research design refers to the logical structure of research inquiry whereas research method refers to a mode of data collection. Research method is only a subset of research design as shown in figure 5.1.



Adapted from Saunders et al., 2007; Kumar, 2010

Figure 5.1 Research design

The choice of the research design depends on the researcher's philosophical paradigm. It is important for a researcher to make explicit which paradigm his work will draw on since a clear philosophical and methodological stance helps justify his design decision (Easterby-Smith et al., 2012). There are two drivers that jointly influence the choice of the design.

1. The nature of the research questions and the kind of output that answers the research questions
2. Personal preferences or philosophical assumptions of the researcher

Personal preferences develop through the course of his life and are influenced by his background, education, interest and work experience. The researcher can map his way of scoping his research design by choosing his preferred type of ontology and his preferred philosophical paradigm (epistemology). He can proceed with his research design that covers approach, research strategy, methodology, methods, and techniques (Figure 5.1). The following sections discuss the research design for the present research- research strategies (Quantitative vs. Qualitative), research methods (data collection techniques), and finally research quality criteria.

5.1.1 Quantitative and qualitative distinction

Quantitative and qualitative research form the two distinctive clusters of research strategy, and they differ with respect to their epistemological and ontological foundations. Table 5.1 displays the differences between quantitative and qualitative research in terms of their processes.

Quantitative research strategy emphasizes a deductive approach and mainly used for testing theories; It incorporates the method adopted in natural science and thus positivism, and embodies a view of objective reality. Qualitative research strategy emphasizes an inductive approach and mainly used for generation of theories; it incorporates the ways in which individuals interpret their social world, and embodies a view of social reality (Bryman, 2008). Although qualitative strategy is used for generating theories, it can also be employed for testing theories (Yin, 2009).

Quantitative research can be construed as a research strategy that emphasizes quantitative in the collection and analysis of data, whereas, Qualitative research can be construed as a research strategy that usually emphasizes words rather than quantification in the collection and analysis of data. Quantitative research is positivism and views social reality as an external and objective reality. Qualitative research entails interpretation and views social reality as a constantly shifting emergent property of an individual creation.

Table 5.1 Difference between Quantitative and Qualitative research strategies
(Adopted from Cooper and Schindler, 2006:199; Bryman and Bell, 2007:28; Stake, 1995:37; Martinez-Hernandez, 2005:64)

Processes	**Quantitative**	**Qualitative**
Focus of research	Describe, explain and predict	Understand and interpret
Principal orientation to the role of theory	Deductive (testing a theory)	Inductive (generation of theory)
Epistemology	Positivism	Phenomenology
Ontology	Objectivism	Subjectivity (Constructionism)
Sample size	Large	Small
Data type	Quantitative (numerical)	Mainly verbal (description)
Data analysis	Statistical techniques	Interpretation and pattern making
Data validity	Rely on statistical techniques, past research	Rely on the participants and researcher

5.1.1.2 Mixed methods Design

Even though they represent two different paradigms (Easterby-Smith *et al*., 2012; Smith, 1983), qualitative and quantitative strategies can be combined within an overall research project. This is referred to as *mixed methods approach* and seems to be a valuable approach. Mixed methods research directly refers to or stands for research that integrates quantitative and qualitative research strategies within a single project. It is highly viewed that the use of more than one method produce stronger inferences, answer research questions that other methodologies could not, and allow for greater diversity of findings (Creswell & Clark, 2007; Teddlie & Tashakkori, 2003). If the conclusions are the same, the research will lead to greater validity and reliability than a single method approach (Denzin and Lincoln, 2000). This approach helps in combining the advantages of both qualitative and quantitative strategies within a single project (Bryman and Bell, 2007, Creswell and Clark, 2007; Teddlie and Tashakkori, 2009). Different methods can be applied for different purposes in the study. One may wish to employ case study methods, for example, interviews, along with a survey research, in order to get a feel for the key issues. This would give the researcher confidence that he is addressing the most right and important issues (Suanders et al., 2007). Pros and cons of mixed methods are given in Table 5.2

The number of research employing a mixed methods approach has increased since early 1980s and has now become a distinctive approach (Bryman, 2008). Three approaches to mixed methods research are proposed by Hammersley (1996):

(1) One strategy is used to corroborate the other *(triangulation)*;

(2) One strategy is used to aid the other strategy *(facilitation)*; and

(3) Two strategies are employed in order that different aspects of an investigation can be dovetailed *(complementarity).*

Table 5.2 Pros and cons of mixed methods research (Adapted from Easterby-Smith et al. 2012)

For	**Against**
Increase confidence and credibility in the results	Replication is difficult
Increase validity	Research design must be relevant to the research question
Stimulate creative and inventive methods	
Can uncover deviant dimensions	They provide no help if the questions are not appropriate
Can help synthesis and integration of theories	They take up more resources than a single method studies
May serve as a critical test of competing theories	Their use requires a competent overall design
Can combine confirmatory and exploratory research at the same time	The researcher needs to have skills in both the methods
Present greater diversity of views	
Provide better and stronger inferences	

Like mono-method approach, mixed method design must be appropriate to the research questions. While forming a mixed method design, researcher should also consider a broader framework of his research taking into account of his philosophical position. Three basic mixed method design are being used: *Convergent design or compensatory design*, where quantitative and qualitative results are compared, and each is used to make up for the weakness of the other; *Explanatory Sequential design*, where quantitative results are further explained (to extend and amplify) by qualitative data and results; and *Exploratory sequential* design where qualitative exploration leading to a quantitative test.

In this research, qualitative research strategy (multiple case study research) was used to corroborate the quantitative research strategy (survey research), and thus triangulation. In the first phase of the research, the researcher collected data using a survey instrument, and in the second phase of the research, the researcher conducted multiple case studies using interviews to conduct an in-depth investigation into the phenomenon of interest. The research approach is displayed in Figure 5.2. Data collection was done sequentially, survey research followed by case study research. The analyses were also done separately, and the findings of the qualitative data analysis were used to support and corroborate the conclusions of the quantitative data analysis. In addition, the conceptual framework developed in chapter 3 was used to guide both these two phases of the research. Thus, the broad approach used in this research is a holistic, mixed methods study (Bryman, 2008; Cresswell, 2003), where multiple studies using a range of qualitative and quantitative methods explore different facets of a common conceptual framework – learning in Six Sigma project teams.

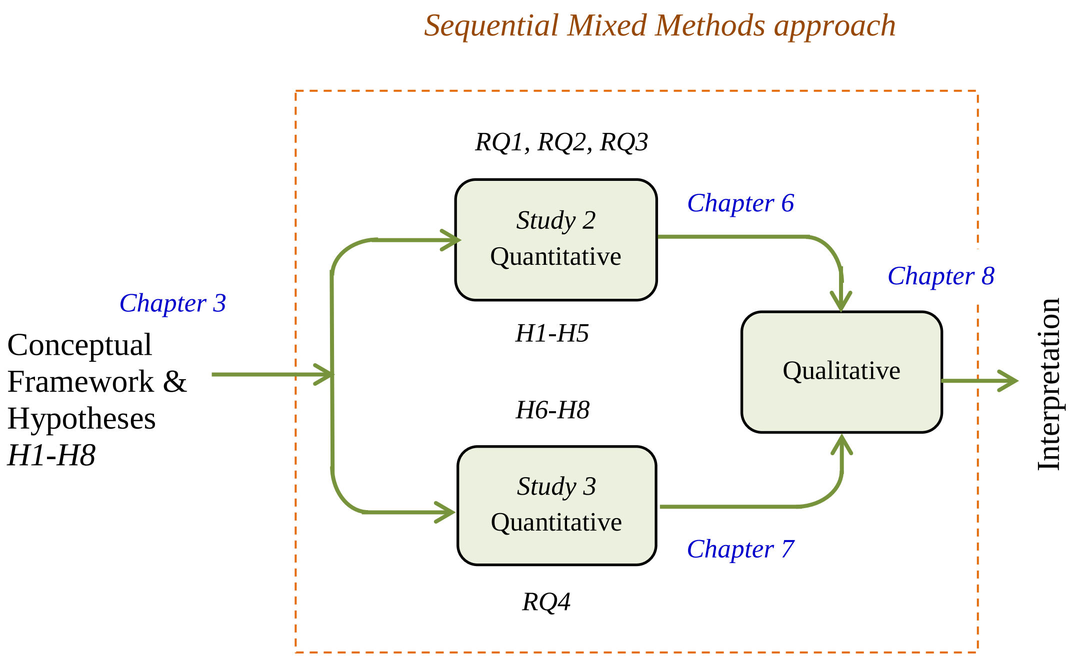


Figure 5.2 Research approach

In spite of its several advantages, conducting a mixed methods research has always been a challenging endeavor. The main issues are time and resources required to collect and analyze the qualitative and quantitative data. In addition, the researcher needs to have a proper understanding and skills in both the methods (Creswell and Clark, 2007). Fortunately, the researcher had a good quantitative background and acquired and developed understanding of qualitative data analysis, as a part of the curriculum. By attending several conferences and workshops, the researcher could gain a better understanding of the qualitative data analysis.

5.1.1.3 Research flow diagram

Figure 5.3 shows research flow diagram that explains various phases of the research processes. The arrrows linking various stages of quantitative and qualitataive studies indicate the linkage between these two research strategies. The main links are:

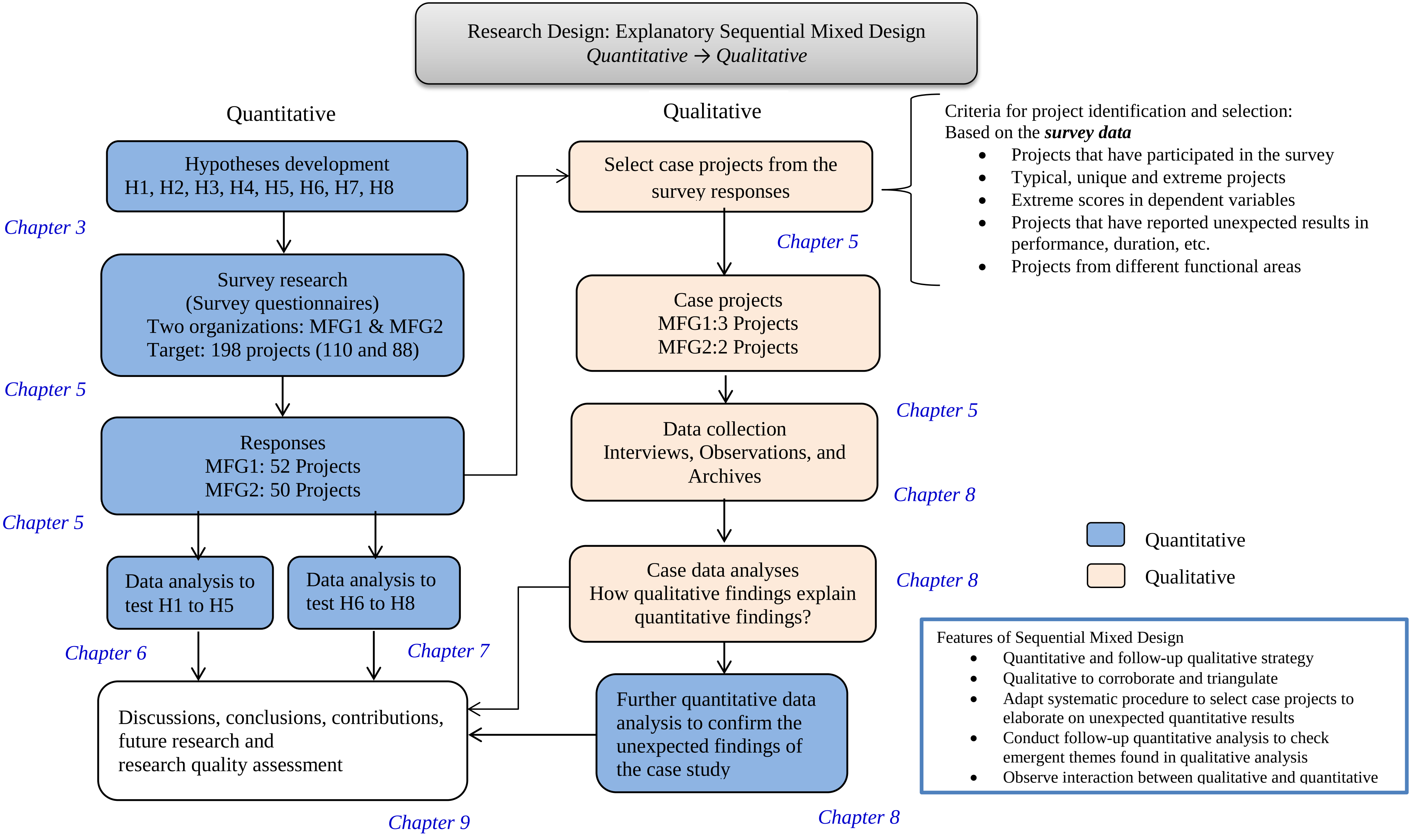
(1) Selection of case projects (based on the survey data, and using certain seletion criteria)

(2) How does qualitative data analysis explain quantitative results?

(3) Further quantitative data analysis to confirm the unexpected findings of qualitative data

The details are explained in the next sections.

Creswell and Clark (2007) suggest the use of visual diagrams to display the methods, procedure, and products of mixed methods studies. It is a useful tool to communicate the complexities inherent in the mixed methods research. Figure 5.4 shows the visual representation of the research approach, explaining various aspects of data collection and analysis, including tools, procedures, and outcome expected.



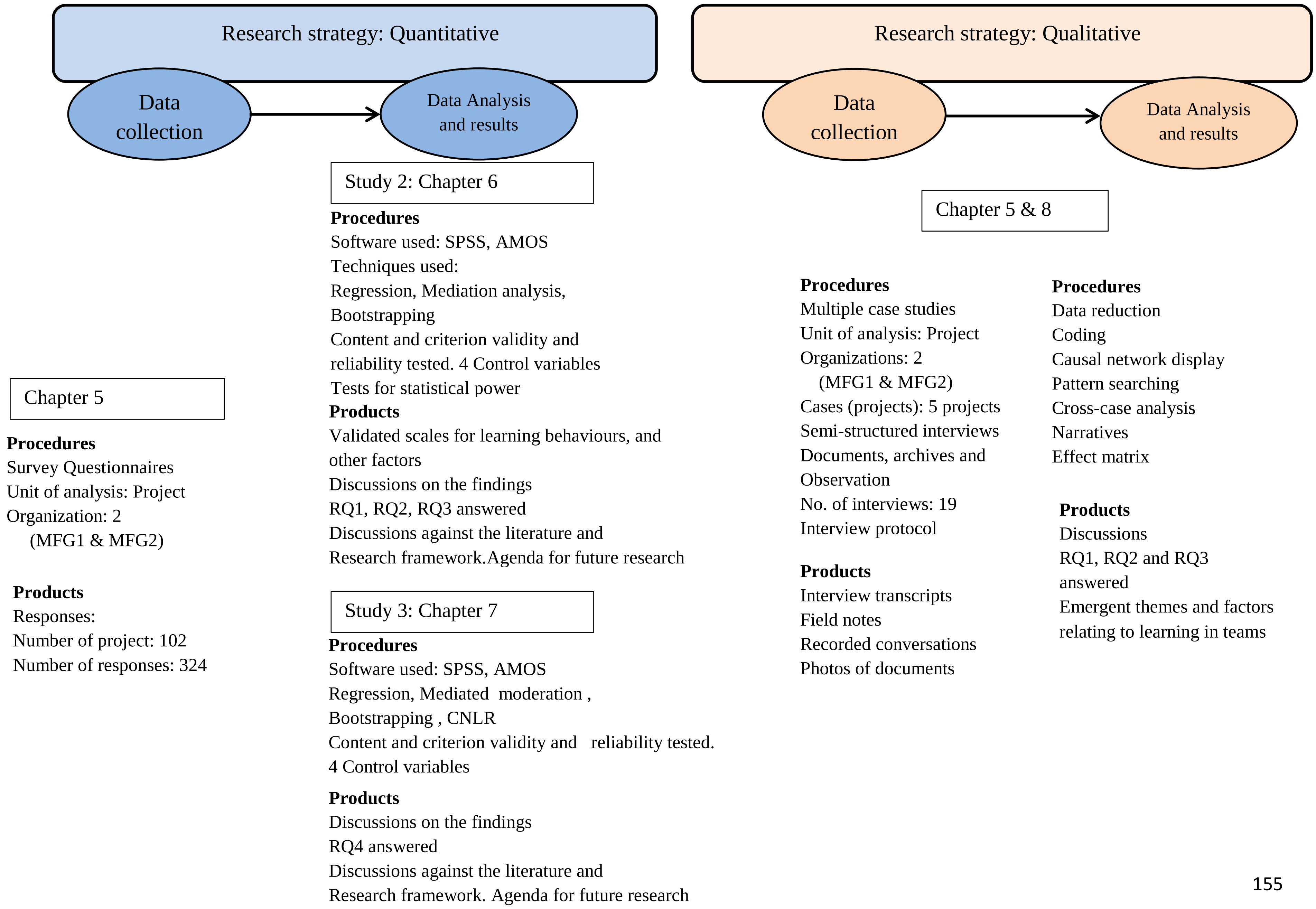
Criteria for project identification and selection:
Based on the ***survey data***

- Projects that have participated in the survey
- Typical, unique and extreme projects
- Extreme scores in dependent variables
- Projects that have reported unexpected results in performance, duration, etc.
- Projects from different functional areas

Features of Sequential Mixed Design

- Quantitative and follow-up qualitative strategy
- Qualitative to corroborate and triangulate
- Adapt systematic procedure to select case projects to elaborate on unexpected quantitative results
- Conduct follow-up quantitative analysis to check emergent themes found in qualitative analysis
- Observe interaction between qualitative and quantitative

Figure 5.3 Research flow diagram



Chapter 5

Procedures
Survey Questionnaires
Unit of analysis: Project
Organization: 2
(MFG1 & MFG2)

Products
Responses:
Number of project: 102
Number of responses: 324

Study 2: Chapter 6

Procedures
Software used: SPSS, AMOS
Techniques used:
Regression, Mediation analysis,
Bootstrapping
Content and criterion validity and
reliability tested. 4 Control variables
Tests for statistical power
Products
Validated scales for learning behaviours, and
other factors
Discussions on the findings
RQ1, RQ2, RQ3 answered
Discussions against the literature and
Research framework.Agenda for future research

Study 3: Chapter 7

Procedures
Software used: SPSS, AMOS
Regression, Mediated moderation ,
Bootstrapping , CNLR
Content and criterion validity and reliability tested.
4 Control variables

Products
Discussions on the findings
RQ4 answered
Discussions against the literature and
Research framework. Agenda for future research

Chapter 5 & 8

Procedures
Multiple case studies
Unit of analysis: Project
Organizations: 2
(MFG1 & MFG2)
Cases (projects): 5 projects
Semi-structured interviews
Documents, archives and
Observation
No. of interviews: 19
Interview protocol

Products
Interview transcripts
Field notes
Recorded conversations
Photos of documents

Procedures
Data reduction
Coding
Causal network display
Pattern searching
Cross-case analysis
Narratives
Effect matrix

Products
Discussions
RQ1, RQ2 and RQ3
answered
Emergent themes and factors
relating to learning in teams

Figure 5.4 Visual representation of Research Design used in the research

5.1.2 Research strategy for this research

As discussed in the previous sections, an objective ontology, a positivist epistemology and deductive are deemed to be the most appropriate for this research. The available approaches include case studies, action research, ethnography and grounded theory for inductive research and survey and experimental for deductive research. The researcher's responsibility is to choose strategies that are most appropriate and advantageous for the questions, the one that will provide reliable answer to the research questions, taking into account of his philosophical paradigm, his skills, and the resource availability. The researcher decided to carry out survey research to answer the research questions in the phase one of the research, followed by a case study research in the second phase. The following section will discuss the justification for the choices made.

5.1.2.1 Survey research followed by case research design addressing this research (mixed-methods research)

The research questions aim to study more of 'what' on the concept of learning behaviours and factors that influence these behaviours. The researcher is seeking detailed evidence into activities and processes summarized in the conceptual model developed earlier in chapter 3 (Figure 3.3). Research question 1 aims to examine learning behaviours or learning activities that might be formal or embedded in organizations in Six Sigma project contexts. Research questions 2 to 4 aim to investigate the causal linkage between various factors, learning behaviours and performance. Comparing the use of survey research and case research, survey research is suited for answering 'who', 'what', 'where', 'how much' and 'how many' questions; and case study is most suited for 'how' and 'why' questions. The researcher is seeking empirical evidence into activities and factors that affect those activities summarized in the conceptual model. Given the type of research issues, survey research with a large sample of data and multivariate analysis is therefore considered as a valid and most advantageous method for answering the research questions RQ2, RQ3 and RQ4, as can be supported by the following.

- The researcher aims to conceptualize learning behaviours based on the extant research, develop suitable measurement scales for these learning behaviours and validate statistically, and subsequently investigate empirically the causal linkage between learning behaviours, project level antecedents and performance consequence. The researcher develops hypotheses on these relationships and aims to test using the empirical data from a large sample. Therefore, survey research is more suitable for this research (Easterby-Smith et al., 2012; Bryman, 2008; Saunders et al., 2000).

- The research questions call for theorizing and confirming of one or more aspects of the Six Sigma phenomenon. The research calls for an explanatory study, associating social and technical factors with learning and project performance (organizational and project level factors, learning behaviours, project performance). Survey research is mostly suited for explanatory research (Bryman, 2008; Saunders et al., 2000).
- Surveys are commonly used methods in the positivist paradigm in order to achieve systematic observation, interviewing and questioning through predetermined research questions with the intention of providing standardization and consistency (Fink, 2005; Moser & Kalton, 1971; Scholarios, 2005).
- Surveys are also appropriate methods when the researcher has a higher control over the situation and high participation. Survey method is appropriate to use while answering "what" research questions (Yin, 2003b).

The survey, which is a traditional and common strategy in business and management research is followed by a qualitative research. In the quantitative phase of the research, the study aims to test the theory with a broad cross-section of projects from the sample firms. Since the research investigates the hitherto unexplored learning behaviours, it is also decided to conduct a qualitative study to enrich the theory by grounding it with relevance and meaning. Thus, a mixed-method approach to empirical investigation is used in order to arrive at a more comprehensive understanding of the phenomenon under study. The case research can help explain and corroborate the quantitative results through the qualitative data analysis and thus the research design is *explanatory sequential design* (Bryaman, 2008; Saunders et al., 2007). By mixed-methods research, the result of the survey research investigation is cross checked by the results of the qualitative research.

Thus, the mixed method research is used for triangulation (Hammersely, 1996; Bryman, 2008). The survey phase of the research plays a major role, and the case study a supporting role. Further,

- The case study has considerable ability to generate answers to the question ‘why?’ as well as ‘what?’ and ‘how?’ questions (Robson, 1993). It is possible, therefore, to get some insights into ‘why?’ aspects of the phenomenon along with ‘what’ and ‘how’ which are investigated in survey research.
- Case study can be a very worthwhile way of exploring the existing theory as well as it can enable to challenge an existing theory and also provide a source of new hypothesis (Saunders et al., 2007). This is particularly worthwhile, as the learning phenomenon under investigation is new and hitherto unexplored.
- The quantitative and the qualitative data deriving from mixed methods will provide triangulation of data for greater validity (Bryman, 2008). The mixed method design will provide more significant enhancement of the validity of the research outcome and hence will have greater credibility among researchers and practitioners.
- The use of more than one method produces stronger inferences, answers the research questions that other methodologies could not, and allow for greater diversity of findings (Creswell & Clark, 2007; Teddlie & Tashakkori, 2003).
- Finally, the researcher also wants to leave open the possibility of coming up with *unanticipated findings* from the open-ended qualitative research that can give more insights into the phenomenon (Bryman, 2008).
- Qualitative research might provide contextual understanding coupled with either generalizable, externally valid findings or broad *relationships among variables* uncovered through a survey research (Bryman, 2006).

In case study research, as Meredith (1998) argues, “understanding that is achieved is only meaningful within a framework of assumptions, beliefs, and perspectives specified by the researcher” (1998, p. 443), the conceptual framework developed in chapter 3 thus serves as the theoretical lens or “frame of reference” in the case study inquiry.

Table 5.3 Research method choice for this research (Adapted from Yin, 2009)

Method	**Form of research question**	**Requires control of behavioural events?**	**Having access and resources?**	**Does the method apply to this research?**
Survey	Who, what, where, how many and how much?	No	Yes	Yes
Case study	How, why?	No	Yes	Yes

Table 5.3 summarizes the selection choices on the methods based on the selection criteria by Yin (2009). In order to test hypotheses *H1* to *H8*, and answer research question *RQ1*, *RQ2*, *RQ3* and *RQ4*, survey research is proposed. The findings of the research questions *RQ1*, *RQ2*, and *RQ3*, will be further explained through a case research.

5.1.2.2 Survey research versus experiments

Experimental method involves random assignment of subject to either an *experimental* or *control* group. Conditions for the experimental group subjects are then manipulated to assess the impact of the conditions in comparison with the control group, who receive no special conditions (Easterby-Smith et al., 2012). This approach is adopted in medicine and natural sciences. Another type of the experimental method is *quasi-experimental* method, wherein the allocation of control and experimental group is not randomized. Here the allocation takes place on some other criterion, usually by using intact groups. In an experimental design, the researcher has direct, precise and systematic control over the behaviour of the variables under inspection (Yin, 2009) which is not required in this research. As the questions and the research aims reflect, the researcher does not seek to control or influence the learning processes in Six Sigma project contexts as normally done in any experimental research. Rather, the researcher aims to understand and clarify how team members are going about learning to solve problems in projects, and how those practices or behaviours are put into action as they happen in real process improvement project settings. The research questions do not demand any control on the actual process, but aim to get insight into the real process. Therefore, experimental design is not considered in this research. Moreover, it is a general belief that experiments are commonly used methods in physical sciences and are impractical in management research (Beech, 2005). Therefore, survey method is chosen in this research.

5.1.2.3 Case research versus participation, ethnography, discourse analysis and grounded theory

Grounded theory formulated by Glaser and Strauss in 1967 is to develop a theory from the data generated by a series of observations/fieldwork in the process of conducting research (Saunders *et al*., 2007). In Grounded theory, research starts with no presuppositions, and the researcher should allow ideas to emerge from the data (Glaster, 1992). Having familiarized with prior research, the researcher should use a structured process to make sense of the data (Strauss, 1987), and he needs to articulate his position when writing his research. The primary aim is to generate theory, and the researcher has to allow a substantive theory to emerge from the data. Data analysis proceeds from identifying categories, properties and dimensions through examining conditions, strategies and consequences around an emerging storyline. As the present research starts a conceptual framework and a set of research questions, case study survey research is more suitable for this research.

Although the other methods such as participant observation, ethnography, or discourse analysis would be appropriate for this research, due to resource constraints and access limitations, case study research is considered to be more appropriate. Moreover, these methods are commonly employed within grounded theory approach and are closer to interpretivist epistemology, and may require a longer period (longitudinal design). Therefore, case study research appears to be more advantageous in this study.

5.1.2.4 Action research and Cooperative inquiry

Action research assumes that social phenomena are continually changing rather than static. Researchers often part of the change process itself, by involving himself in the change initiatives in organizations. Although action research falls within the principles of constructionism, some form of action research appears to follow the principles of positivism, such as attempting to change the organization from outside and then measuring the results (Easterby-Smith et al., 2012). The research focuses upon resolving issues and facilitates change. By involving himself, he also focuses on holistic and contextual understanding of phenomena. Action research facilitates incremental theory building, and generalization takes place through conceptualization of a particular experience and linking to the theory (Saunders *et* al., 2007). The present research's aim is not to introduce or facilitate any change initiatives in an organization, but rather to investigate how learning takes place in six Sigma project teams. Hence, action research is not suitable for the present research.

5.1.3 Survey Research addressing this study

Positivist method usually starts either with the assumption of some hypotheses about the nature of the world, and the researcher then seeks data to confirm or disconfirm it or the researcher poses several hypotheses, and seeks data that will help him to select the correct one (Easterby-Smith et al., 2012). Survey research uses *cross-sectional design* with a large sample of data to enable the researcher to measure multiple factors simultaneously and establish potential underlying relationship. Usually, they are known as *cross-sectional* surveys, as they involve selecting different organizations, or units, in different contexts and investigating how other factors, measured at the same time, vary across these units.

Survey research is the most dominant form of data collection in the social sciences, providing for efficient collection of data over broad populations, amenable to administration in person, by telephone, or over the Internet (Easterby-Smith *et al*., 2002; Saunders *et al*., 2000). ''A survey is a systematic method of gathering information from (a sample of) entities for the purpose of constructing a quantitative description of the attributes of the larger population of which the entities are members'' (Groves et al., 2009:2). The descriptors are either descriptive statistics or analytic statistics displaying relationships.

There are three types of survey research (Table 5.4). *Exploratory is* carried out during the early stages of research into a phenomenon, when the objective is to gain preliminary insight on a topic and to get basics for more in-depth survey (Forza, 2002; Malhotra and Grover, 1998). It helps to uncover preliminary evidence of the association among concepts. It also can help to determine the concepts to be measured, how best to measure them and how to discover new facets of the phenomenon (Forza, 2002). *Explanatory survey* is usually used for theory testing or to provide an explanation to a theory and develop refinement of an existing theory. The primary purpose of the research is to test the adequacy of the concepts, hypothesized linkage between concepts and the validity boundary of the models (Forza, 2002; Malhotra and Grover, 1998).

Table 5.4 Survey research types (Forza, 2002)

Elements	**Exploratory**	**Descriptive**	**Explanatory**
Unit of analysis	Clearly defined	Clearly defined and appropriate for the research questions	Clearly defined and appropriate for the research questions
Respondents	Representative of the unit of analysis	Representative of the unit of analysis	Representative of the unit of analysis
Initial hypothesis	Not required	Questions clearly stated	Hypothesis
Sample frame	Approximation	Explicit and logical argument to choose among alternatives	Explicit and logical argument to choose among alternatives
Sample	Not a criterion	Systematic, purposive, random selection	Systematic, purposive, random selection
Sample size	Sufficient to include the range of the interest phenomena	Sufficient to represent the population and conduct statistical analysis	Sufficient to test categories in the theoretical framework with statistical power
Pre-test of questionnaires	With sub-sample of the sample	With sub-sample of the sample	With sub-sample of the sample
Response rate	No Minimum	Greater than 50% of targeted population and study of bias	Greater than 50% of targeted population and study of bias
Data triangulation	Multiple methods	Not necessary	Multiple methods

Source Forza, 2002

Descriptive survey is aimed at describing the distribution of the phenomenon in a population, thereby ascertaining facts. The survey involves collecting and collating relatively factual data from different groups of people. From the descriptive survey, researchers can draw useful hints both for theory building and theory refinement.

For this Doctoral study, an explanatory survey is used in the first phase of research to examine the learning behaviours in Six Sigma teams and the causal relationship between the managerial factors and learning behaviours and project performance.

5.1.3.1 Unit of analysis

The unit of analysis refers to the level of data aggregation during subsequent data analysis (Forza, 2002). The unit of analysis may vary from a person to departments, organizations, decisions, programs, the implementation process, and organizational change (Flynn et al., 1990; Yin, 2009). It is related to the way a researcher defines his research questions (Yin, 2009), and it is necessary to determine the unit of analysis when formulating the research question (Forza, 2002). Ill-defined research questions, therefore, lead to the wrong selection of the unit of analysis leading to a less focused research inquiry. Data collection methods, sample size, and the construct operationalization may be determined or guided by the unit of analysis. Collecting data at one level and interpreting the result at another level lead to cross-level inference problem. At the very outset, therefore, one must define the unit of analysis. The research questions set for the present research aim to investigate the learning behaviours of Six Sigma project team and understand the underlying activities and practices within Six Sigma project teams. Hence, the unit of analysis in this research is Six Sigma project. Since leaders and members work through projects, they are likely to have used various learning practices to solve problems in their project. They are, therefore, knowledgeable to respond to questions about the learning behaviours used to solve problems in their projects and factors that have affected their learning behaviours and performance. The survey instruments used in this research, therefore, were targeted at the project leaders and members of the sample projects (Forza, 2002; Rungtusanatham et al., 2003).

5.1.3.2 Data collection method for survey research

Figure 5.4 outlines the main methods of data collection in survey research (Bryman, 2008). Self-completion questionnaire (also called as self-administered) and structured interview are the two methods employed in survey research. Questionnaires that are completed by respondents themselves are one of the main instruments for gathering data in survey research. It can be a postal or through the internet. Sometimes self-completed questionnaire is administered with the help of a person engaged by the researcher. Postal questionnaire is sent through the post to the selected respondents. The respondents are requested to send the questionnaire following completion by post. Due to the recent popularity and increasing access level of the internet, most of the self-completion questionnaires are administered via

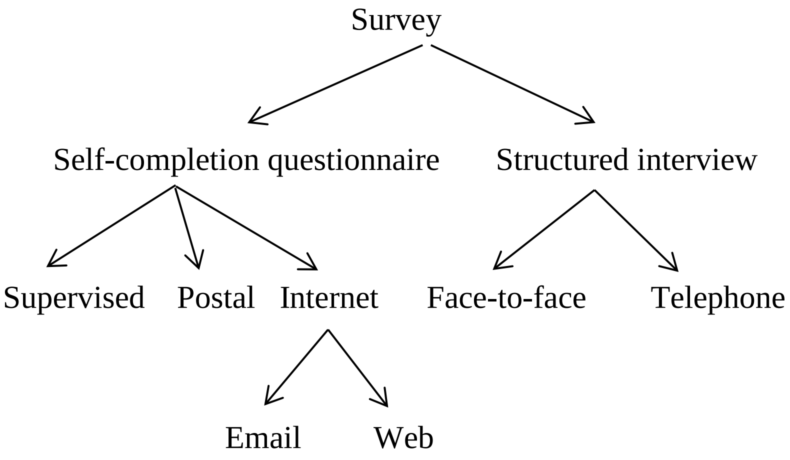


Figure 5.5 Main methods of data collection in survey research (Bryman, 2008)

internet, either web-based or email survey. With email surveys, the questionnaire is either embedded or attached to the email. In the case of the embedded questionnaire, the questions are to be found in the body of the email. There may be some introduction to the questionnaire and respondents are asked to indicate their answer using some notation such as ‘x’, or they may be asked to delete the alternatives that do not apply. For open type questions, they may be asked to type in their answers. The respondents are requested to send their responses by reply mails. Web surveys operate by inviting prospective respondents to visit the website at which the questionnaire can be found, and they can complete their answers online. Or, the survey link containing the questionnaire will be attached to an email to the respondent, and on clicking the link, a web page opens up for respondents to complete. The web-based survey is a standard approach now. Functionality and interactivity available in a web-based system help explain or give instructions to the respondents. Finally, respondents' answers can be automatically downloaded into a database, thus eliminating the daunting coding of a vast number of questionnaires. This saves time and also reduces the likelihood of errors in the processing of data. There are a number of commercial web-based software applications available that are widely used by academia. By using these software packages, one can design the questionnaire online and then create a web address for each to which the respondent can be directed. Limitations of self-completed questionnaire:

- Questions need to be clear and unambiguous as no one will be available for help
- Difficult to ask a lot of questions, as it may lead to non-response
- Greater risk of missing data
- The low response rate

In a structured interview process (also called as a standardized interview), the interviewer elicits information from the interviewee using interview schedule. The aim is to give exactly the same context of questioning to all interviewees so that all of them provide responses to identical cues. This is to ensure that interviewees' replies can be aggregated for analysis. The interviewer reads out questions exactly and in the same order as they are printed on the schedule. Questions are very specific and offer a fixed range of answers (closed-ended). Structured interview may be administered in person (face-to-face) or over the telephone. Interviewer's attributes such as ethnicity, gender, and socioeconomic status may affect the responses.

Table 5.5 shows comparisons between structured interviews and self-completion questionnaire. Telephone surveys and personal interviews are expensive and time-consuming to administer, but they permit clarification or explanation of items, reduce the number of incomplete responses and may increase the response rate. Table 5.6 compares the different methods of administering the survey.

Table 5.5 Comparison between self-completion questionnaire and a structured interview in survey research (Bryman, 2008; Saunders et al., 2007)

Self-completion questionnaire	**Structured Interview**
Cheaper to administer	Expensive
Geographically dispersed samples can be targeted	Time and cost for the interviewer
Quicker to administer	Takes a long time to administer a large size sample
Can be distributed for a larger size of samples at the same time	
Responses may not come immediately. Reminders/follow up mail to be sent	Responses are immediate
They can complete a questionnaire when they want and at what speed they want to do	
Absence of interviewer effects	Characteristics of the interviewer affect the answers
Do not suffer from interviewer variability	Ethnicity, gender and social background may bias the responses

- Email survey using an attached web-based questionnaire was planned and executed for the survey for the following reasons.
- It is easier to administer the survey by the respective organizations through email ids of the individuals.
- Emails with attached web-based questionnaire can be sent to all members of the sample projects across the organizations at the same time
- Functionality and interactivity available in the web-based system help explain or give instructions to the respondents, thereby increase the response rate.
- Able to track and monitor the progress and send reminders to non-respondents
- Minimize the impact of the interviewer
- Cheaper to conduct the survey
- More convenient for respondents, because they can complete a questionnaire when they want and at the speed that they want to do

Table 5.6 Comparison of different modes of survey administration
(Source: Bryman et al., 2008)

Issues	Email	Web	Face-to-face interview	Telephone interview	Postal questionnaire
Resources					
Cost is low	√ √ √	√	√	√ √	√ √ √
Speed is faster	√ √ √	√ √ √	√	√ √ √	√ √ √
Cost of handling sample low	√ √ √	√ √ √	√	√ √ √	√ √ √
Sampling related					
Good response rate	√	√	√ √ √	√ √	√
Able to control on who responds	√ √	√ √	√ √ √	√ √ √	√ √
Accessible to all sample members	√	√	√ √ √	√ √	√ √ √
Questionnaire					
Suitable for long questionnaire	√ √	√ √	√ √ √	√ √	√ √
Suitable for complex questions	√ √	√ √	√ √ √	√	√ √
Suitable for open questions	√ √	√	√ √ √	√ √	√
Suitable for filter questions	√	√ √ √	√ √ √	√ √ √	√
Control over the order of the questions	√	√ √	√ √ √	√ √ √	√
Suitable for sensitive questions	√ √ √	√ √ √	√	√√	√ √ √
Less likely to result in non-response to some questions	√ √	√ √	√ √ √	√ √ √	√ √
Allow visual aids	√ √	√ √ √	√ √ √	√	√ √ √
Answering context					
The opportunity to consult others	√ √ √	√ √ √	√ √	√	√ √ √
Minimize the impact of interviewers	√ √ √	√ √ √	√	√ √	√ √ √
Minimize the impact of the social desirability effect	√ √ √	√ √ √	√	√ √	√ √ √

Note: Number of ticks (√) indicates the strength of the mode of administration of a questionnaire in relation to each issue.

5.2. Survey research design

The following steps were followed in the survey research: (Esterby –Smith et al., 2012; Bryman, 2008):

- Sampling design
- Questionnaire design
- Collecting data through survey
- Summarizing and making inferences from data through suitable statistical analysis techniques

Survey method using self-reported questionnaire was used to collect data from Six Sigma project teams, and the data were used to test the hypotheses developed for addressing the research questions in chapters 6 and 7. Details of the questionnaire and the data collection will be discussed in this chapter, and analysis will be explained in the respective chapters (Chapters 6 and 7). Multivariate analysis using SPSS Statistics software version 22 and AMOS was used for data analysis.

5.2.1 Sampling design and Research settings

Before discussing the sample for the research, it is required to define various terms used in sampling design. *Target population*: The target population is a group of entity for which the survey researcher wants to make inferences by using the sample statistics. The *population* refers to the whole set of entities that decision relates to, and *sample* refers to a subset of those entities from which evidence is gathered. An Inference is made by making use of the evidence collected from the sample to draw conclusions about the population. If the sample has the same characteristics of the population from which it is drawn, then the accuracy of the findings is considered to be good. A sample is said to be *biased* if the sample is systematically different in some way. For example, if some members of the population have a higher chance of being included in the sample than others, then the sample is biased. Every effort must be to be taken by the researcher to avoid bias in sampling in order to get accurate inference from the study. *Precision* in sampling is another criterion that refers to how credible a sample is. It is related to sampling proportion and sample size.

The sampling frame is the list of all eligible entities to be included in the study. It simply means the available material for sample selection. Sampling frame in its simplest form consists of a list of population elements. There may be a list of populations readily available for the researcher. For example, members of a professional organization, members of industry- society, business establishments located in a particular country or region, etc. There may also available registries of addresses in the country or the list of addresses of organization in any authorized databases.

Sample designs can be grouped into two families: probabilistic and non-probabilistic sampling. In probabilistic sampling, the population subjects have some known probability of being included into the sample. When other considerations such as availability, obtaining information relevant to and available only from certain groups, and time, then non-probabilistic sampling is usually chosen (Forza, 2002; Babbie, 1990). Table 5.7 describes the different sampling approaches in probabilistic sand non-probabilistic sampling.

Sampling error: Error in findings brought out because of the difference between the sample and the population from which it is selected. This may occur even in cases where probability sampling has been employed.

Non-sampling error: Error in findings due to the difference between the population and the sample because of either inadequate sampling frame or poor questions or wrong data processing and analysis.

In survey research, often the researcher encounters the problem of non-response from the sample. If those who do respond have the same characteristics as those who do not, then the non-response is not a problem. As it is assumed that the slow responders will be more similar to non-responders, it is generally accepted if the researcher can show that the slow responders and rapid responders have similar characteristics. The researcher needs to take steps while designing sampling to reduce the above shortcomings.

Table 5.7 Sampling approaches

Probability sampling designs	
Simple random sampling	Every sample entity such as a person, customer, company, etc., has an equal chance of being included in the sample.
Stratified random sampling	Divide the population into homogeneous groups (called strata), and then apply random sampling within each strata.
Systematic random sampling:	From the list of available population (database) that is of interest to the researcher, random sampling is applied to get a sample.
Cluster sampling	Divide the population into different clusters and then by sampling all the units within the selected clusters.
Non-probability sampling design	
Convenience sampling	Selecting sample units on the basis of how they are easily available
Quota sampling	Divide the relevant population into categories, and then selection of the required number of samples within each category.
Purposive sampling	The researcher decides the number of the sample unit and approaches potential sample members to check whether they satisfy the eligibility criteria.
Snowball sampling	Survey starts with someone who meets the criteria and other samples who are referred by the first sample and who are also eligible

The sample organizations for this research were chosen based on the need for data in order to answer the research questions. Traditionally, Six Sigma started from manufacturing organizations and matured in manufacturing organizations. Subsequently deployment is increasingly seen in other service organizations. Second, the review indicated that the deployment features are the same across industry sectors (Antony et al., 2007, 2008; Schroeder et al., 2008). The results, therefore, can be generalized across industry sectors. Third, the unit of analysis is Six Sigma project as explained earlier. It is possible to get a variety of projects dealing with various functions such as manufacturing, administration, finance, and customer relationship in a manufacturing organization. Therefore, it is highly possible to get heterogeneity in projects with respect to project size, functional representation in each team, and project duration. As a result, we can get high variations in learning behaviours and organizational factors that affect those behaviours in projects, investigation of which is the primary objective of this research.

The selection criteria demand that the case companies needed to deploy Six Sigma and have carried out enough number of projects. In order to gather necessary data to answer the research questions, the researcher needed to get data and receive accurate accounts of project execution from the people involved in projects-project leaders and team members. In addition, the researcher also required data about Six Sigma deployment and the nature of support extended to project teams by the respective management. In other words, researcher needed access to people from top management as well as middle and bottom level hierarchy (Eisenhardt, 1989), and significant historical data and company documents showing Six Sigma deployment and project execution. These criteria necessarily imply a close and, ideally, well-established relationship with the sample organizations. The researcher, therefore, had to adopt an approach different from the conventional method of contacting organizations on any particular mailing list used in most empirical studies involving business units. This required an efficient search for organizations that have deployed Six Sigma, and that would be willing to participate in the research. Fortunately, the researcher is familiar and closely associated with some manufacturing companies through his professional network and professional association. He was able to identify two organizations that agreed to participate in the research, for both the survey and case study. The researcher agreed to maintain the confidentiality of organizations and the data collected. Further, it was promised to use a minimum of their members' time for the survey, and guaranteed for total activities within a short duration, without stretching the overall time frame for too many days.

The two organizations which agreed to participate in the survey are from Europe that deployed Six Sigma for more than four years at the time of the data collection (in the year 2010). Due to the confidentiality agreement with them, the names are withheld. They are called MFG1 and MFG2. Both of them are multinational organizations and have deployed Six Sigma in the entire organizations. Both of them have exclusive Six Sigma organizations to deploy Six Sigma across their functions and regions across the globe. Though both of them are manufacturing, and service as their core business, the product and the nature of the business are different, one is automotive, and the other is the wind industry. The former is a high volume, and the latter is a small volume manufacturing organization. Data from such diverse contexts lend opportunities for multiple comparisons and alternative explanations as themes emerge from the data analysis. Past research shows that various team-level studies have been successfully conducted in a single firm (e.g. Edmondson, 1999; Mukherjee et al., 1998). Only the most recently completed projects (projects completed during the last two years) were identified and selected with the aid of the database from each participating company. This is to minimize the measurement error due to the lack of memory of distant events by respondents (Tversky and Kahneman, 1974). Totally 110 projects from MFG1 and 88 projects from MFG2 were selected (from one business unit from each of MFG1 and MFG2).

During the first introduction visit and a meeting with the corporate deployment champions of MFG1 and MFG2, the researcher explained in detail about the objective of the research and the expectation from the organizations, and potential gain from the research to the organizations. Agreement was reached between the researcher and the organizations about the research and other logistics such as web-based survey and interview schedule and formalities. It was also agreed that the names of the organizations would be kept confidential. The deployment champion or the person appointed as a contact person from the respective organization would be the coordinator and the sole contact person throughout the entire activities. The appointed person from MFG1 and MFG2 took responsibilities for all the work related to survey and the planned visits and all associated activities of the researcher, arranging for the work area visit, meeting and interviewing project leaders and members, visiting work sites, observing and witnessing other artifacts related to projects, and making arrangements to show all documents related to projects.

5.2.1.1 Research sites

MFG1 is a Fortune 500 company with over 40,000 employees worldwide operating in Automotive Original Equipment Manufacturing business. MFG1 operates in more than 40 countries around the globe (Asia Pacific, North America, Latin America, Europe, Middle East, and Africa). With 120 manufacturing units spread in 18 countries and business units in more than 25 countries, the revenue during the year 2009 was approximately 7,400 million Euro.

The primary reason for Six Sigma deployment in MFG1 is Business growth, employee development, and corporate values. The deployment was started in the year 2005 with a well-planned Six Sigma infrastructure, communication plan, HR policy and Finance policy to align the deployment strategy for effective implementation and development across the business units all over the world. MFG1 has documented the cumulative savings of over Euro 168 million from its Six Sigma efforts from 2005.

The organizations for Six Sigma deployment include a corporate Six Sigma board to provide strategic directions, Six Sigma champions for corporate office and Group deployment champion for each business group. Each business unit is provided with a champion and core teams of experts. The deployment champions are certified Master Black Belts and core teams include Black Belts. Trained and certified Green Belts for projects are drawn from operations and other departments. Core teams belong to their respective functions, but functionally report to the deployment champions of the respective divisions or business units.

MFG1 use DMAIC method for manufacturing-related projects and DfSS (Design for Six Sigma) method for design-related projects. More than 1,110 DMAIC projects were completed in the year 2009. Black Belts or experienced Green Belts, who have expertise in tools and techniques lead projects. Total Six Sigma expertise includes 54 Master Black Belts, 427 trained Black Belts and about 2035 Green Belts within the global operation. Of the 427 Black Belts, 193 are specialized in Design for Six Sigma and of the 2035 GB, 169 are trained in Design for Six Sigma. Black Belts are considered to be future leaders of the company. Management shows its commitments toward the project through its active involvement in project selection and prioritization and giving trusted direction. Six Sigma is integrated with major functions such as, people management, financial asset management, customer management, innovation management, demand chain management, and manufacturing management. Our research site is one business unit.

All Six Sigma projects in MFG1 are recorded in the project database system accessible to all employees in the company's official website. The database is designed specifically for tracking, managing and evaluating the Six Sigma process in projects. All project leaders are required to update the progress of their projects on a regular basis using this company-wide database system. People who are engaged in Six Sigma projects can also search for information about the current project status, completed projects, project information, leader, team members, and other persons responsible.

Human Resource Policy of the organization has put in place a re-entry policy for specialists to go back his original or different functions after serving for more than three years as specialists. Black Belts are considered as future leaders, and HR involved in the selection of candidates for BB training. It is interesting to note that the salary review takes place on the day one of the training. Remuneration and recognition are based on their contribution toward Six Sigma projects and deployment. Selection criteria for BB candidates include evidence of high performance, evidence of high potential, proven analytical skills, proven people skills and fluency in English language. Projects are tracked; hard and soft savings are evaluated, savings for 12- month periods are estimated, financial controller signs of the project and the project is followed up through project dashboard.

During the field visit to one of the factories in Sweden, the researcher observed a number of Six Sigma posters, employees wearing T-shirts with Six Sigma emblems, factory board posters, Six Sigma screen savers in employees' laptops. The researcher was also shown Project database (Six Sigma portal) that is accessible to all employees around the globe. The portal is a communications platform showing all about global Six Sigma information, project database, success stories, resources, training schedule and a host of information regarding Six Sigma deployment of the entire business. Visual boards were also found in factory meeting rooms and project offices. The researcher saw the visibility at all levels. Projects are targeted in all functions such as people management, financial asset management, customer management, innovation management, demand chain management, and manufacturing management.

MFG2, a 6billion Euro energy industry with over 16,000 employees worldwide has deployed Six Sigma for the past four years. MFG2 employed DMAIC method for manufacturing and other transactional projects. This is the first company from the wind industry to use Six Sigma. At the time of our survey, the company had about 14 Master Black Belts 47 Black Belts and more than 360 Green Belts trained. The company has a Business Academy for training Black Belt and Green Belts and central deployment office with regional deployment offices around the globe. Green Belt candidates are trained in their respective regions, however, training material is common, and the training methodology is uniform throughout the organization. Each project was also provided with support from an assigned coach, who is either a MBB or a BB. Total number of projects completed during the year 2009 were about 320 and more than 280 projects in the year 2010 at the time of the survey. The company has registered the cumulative savings of about 88 m Euro for the last four years. The company has manufacturing business units in Asia, Europe, and US. Unlike MFG1, no specialists trained in design for Six Sigma were available at the time of the survey. Of the 14 MBB, 5 were not responsible for Six Sigma deployment at the time of the survey, but working with different functions in the organization.

The company has its Six Sigma portal accessible to all employees. The site provides Six Sigma tools and techniques, contact details of experts, study material on Six Sigma, tools and techniques handbook (e-book), project database. It also has training material and sample projects for all trainees. The portal also displays a list of trained experts (GB, BB and MB) available in the organization for consultations. The database maintains all project reports, presentations of completed projects, and details and status of those projects that are under progress. All employees can search for information such as the current projects, completed projects, and project information. The company also supports all its strategic suppliers in their efforts toward deploying Six Sigma. The Business Academy supports strategic suppliers on basic training on Six Sigma to representatives of suppliers and provides technical support for project execution of projects that can enhance the quality of the parts and components produced by suppliers for the company.

HR policy also reflects on the importance of Six Sigma. Knowledge of Six Sigma was considered to be an essential requirement for new recruits. All employees were given training on Six Sigma awareness either at the White Belt (half a day awareness training) or Yellow Belt level (One day training on introduction to Six

Sigma methodology). All senior management team members were exposed to Six Sigma methodology through one-day awareness program.

Projects are selected based on predefined criteria, including the economic benefits, which are estimated in terms of Net Present Value of the expected cost benefits for the next three years. During the initiation of the project, project charter is signed by the project sponsor and financial expert.

5.2.1.2 Data collection for survey research

Activities followed up for data collection are displayed in Figure 5.5.

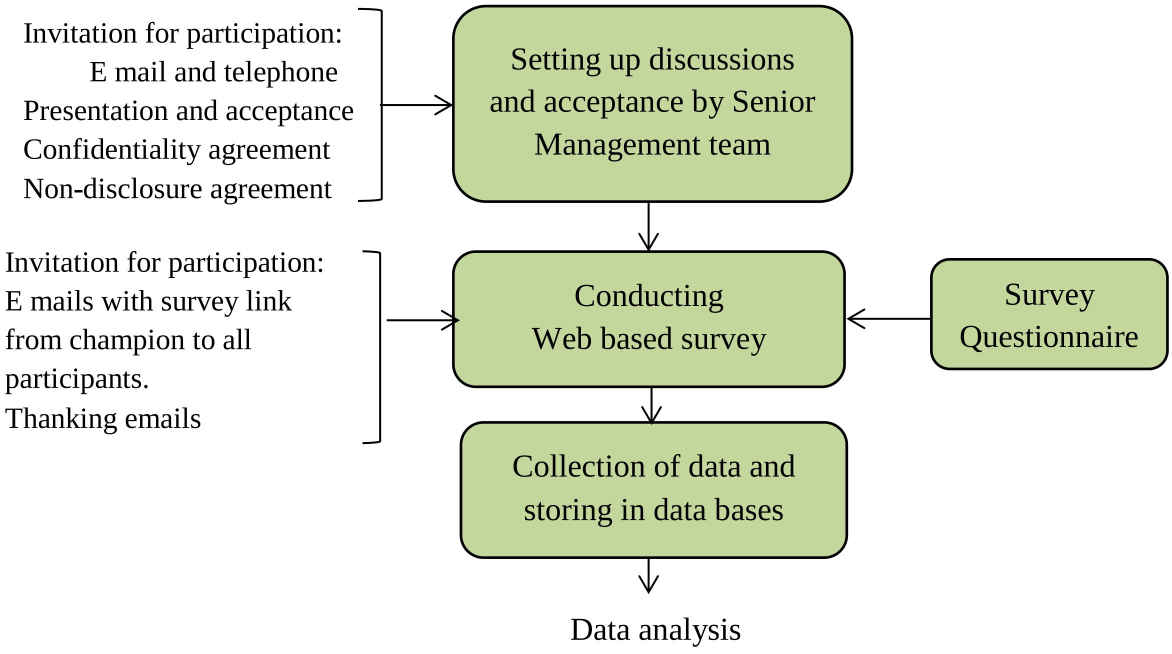


Figure 5.6 Data collection activity map

Only the most recently completed projects by each Black Belt or Green Belts were identified and selected for the survey. This is to minimize the measurement error on the part of the respondents due to the lack of memory for distant events. Project leaders and team members from each selected project were invited to participate in this survey.

5.2.2 Survey questionnaire design

Before developing a questionnaire to collect data from respondents, researcher has to transform the theoretical concepts which he has in his research questions into observable and measurable elements (Forza, 2002). This *operationalization* leads to the selection of one or more questions (scale items) for the construct. The translation from theoretical concepts to operational definitions can be different from construct to construct, with some lend to easy and precise measurement while some do not. Especially, constructs involving things such as people's feelings, attitude and perceptions pose problem to get a precise measurement. Some constructs such as, customer satisfaction have multiple dimensions, and hence these types of constructs have multiple elements. Objective constructs such as, the experience of a project leader in projects can be measured using a single direct question. The development of items to measure constructs using both academic and practical perspectives should help researchers develop better measures (Hensely, 1999). Sometimes, suitable validated measures for one or more of the study constructs may be available from previous studies, which can be adapted if they are appropriate for this study. The following sections explain various constructs and their scale items used in the survey questionnaire for the survey research. Items for the two learning behaviours (Knowing-what and Knowing-how) and project resources were newly developed, and items for the other study variables were adapted from validated scales from the literature. The questionnaire also contains demographic information for the research, which is explained later in this section. Survey questionnaire used in this research is given in Appendix I.

5.2.2.1 Learning behaviour measures

There are differences between learning in new product development (R&D) environments and process-improvement project activity, the focus of the present research. Most of the scales available for learning were created for the former, and nothing was found suitable for this study. In addition, existing scales found in the literature were developed for organization-level studies where the focus is broader knowledge management environments, and not suitable for studies where the focus is team-level activities or processes. Our review found no suitable measures available for Six Sigma resources and learning behaviours (knowing-what and knowing-how dimensions are the two learning behaviours developed in chapter 6). Therefore, new scales for knowing-what, knowing-how and Six Sigma resources were developed which were needed for the study 2 (multivariate analysis). Theoretical background of these two learning behaviours is discussed in chapter 6.

Both knowing-what and knowing-how involves the process of making available and amplifying knowledge created by individuals as well as synthesizing and connecting it to a project's knowledge system. This newfound knowledge helps team members to solve problems. The conceptualization of the two learning behaviors includes both *tacit* and *explicit* knowledge. Tacit knowledge is rooted in action, procedures, routines, commitment, ideas, values and emotions (Nonaka et al. 1996). It is tied to the senses, demonstrative skills, and physical experience. Explicit knowledge is codified knowledge articulated in words, figures, and numbers. It can be easily transferable between individuals. Tacit and explicit knowledge are not two separate types, but inherently inseparable (Adler, 1995). They dynamically interact with each other in creative activities by individuals and groups (Nonaka, 1994). Tacit knowledge is actionable, subjective, and experiential. The interactions emerge through social networking in organizations between people from diverse functions, across business units, people having different mental models and belonging to various social networks. Thus, social interactions between individuals, groups and organizations are fundamental to knowledge transfer. Tacit knowledge is acquired through the social practice of solving problems and thus resides in that practice (Cook and Brown, 1999; Tsoukas, 2003). According to Cook and Brown (1999) new knowledge and novel ways of knowing are generated through the interplay between reflection, thematization, and experience within situated interaction.

Organizational knowledge creation theory construes explicit knowledge as the representation of the tacit knowledge on which it is based (Tsoukas, 2003, 2005). Knowledge is transformed and also enriched when it gradually assumes an explicit form through utterances (Nonaka and von Krog, 2009). Individuals convey the tacit knowledge through utterances and articulate with words, concepts, and linguistic relationships that enable them to convey meaning to themselves and others in the team and thus convey and share certain aspects of tacit knowledge. Team members in Six Sigma projects acquire tacit knowledge through action, practice, and reflection. These practices include group discussions, dialogue with others (customers and suppliers), learning from past experience, observation, reflection and discussions within the team. Through these processes, Six Sigma team learns and creates team level knowledge to solve problems and improve processes. These processes are consistent with Nonaka's knowledge transfer framework: socialization, externalization, combination, and internalization (Nonaka, 1994).

The present research adopted measurement items to capture learning and knowledge transfer that are consistent with the earlier studies in knowledge management literature (e.g., Chou and He, 2004; Becerra-Fernandez and Sabherwal, 2001) and Six Sigma literature (Anand et al., 2010). Similarly to Tucker et al. (2007) and Mukherjee et al. (1998), the researcher developed all measurement scale items for the two learning behaviours based on activities that a Six Sigma team performs to learn and create knowledge in the process improvement project execution. While developing the scales, the researcher referred extensively to quality management, and team-learning literature and related knowledge management scales developed in extant research (Zu et al., 2008; Chakravorty, 2009; Anand et al., 2010; Linderman et al., 2010; Voelpel et al., 2005; Nair et al., 2011; Gutiérrez et al., 2011; Evans and Lindsay, 2005; Hoerl, 2001; Edmondson, 1999; Nadler et al., 2003). The scale items, thus, capture the learning practices found in Six Sigma projects, and include tacit knowledge transfer. Each variable was measured by more than one indicator (scale item). Three academicians from the university and 4 practitioners (2 of them are MBB and three are BB) reviewed the scales for checking and ensuring the *content validity* – the extent to which a measure spans the domain of the construct's theoretical definition (Rungtusanatham, 1998; Churchill, 1979).

The data show that the two learning behavior constructs are reliably measured by processes of learning and knowledge conversion found in Six Sigma projects (Chronbach's alpha: 0.79 and 0.81). The following are the scale items for the two learning behaviours.

Knowing-what

1. We collected information from industry friends outside our team
2. We talked with customers and suppliers about our processes
3. We talked to people having similar experiences in Six Sigma projects to find out what has worked well
4. We reflected on our understanding of the process

Knowing-how

1. We carried out observations to understand the process better
2. We had a number of group discussions to get new information and new ideas
3. We were able to specify the impact of causal variables on project outcome
4. Degree of change implemented was greater on process variables

5.2.2.2 Operationalization of other study variables

Project resources

Each project team is led by trained specialists (Black Belts or Green Belts). Organizations deploying Six Sigma provide necessary resources by setting up belt systems so that competent specialists are available for project execution, information technology support to maintain a robust database for project documentation, and continuously track and monitor all projects and extend necessary support for successful project execution (Antony et al., 2007; Linderman et al., 2010; Pande et al., 2000; Schroeder et al., 2008). The items to measure project resources were adapted from team learning, creativity, project management and Six Sigma literatures (Edmondson, 1999; Amabile et al., 1996; Shenhar, 2001; Schroeder et al., 2008; Antony & Banuelas, 2002).

1. The Belt system was available for consultation
2. Our project sponsor was supportive throughout the project
3. We have systems/databases where we documented our project details
4. Management team provided the necessary support for project execution
5. Management team helped to remove any barriers to project execution
6. We have a hierarchy of expertise like MBB, BB, GB or equivalent

Structured Method/tools

The method being a systematic approach to problem solving tends to lead a project team to a more rational process and helps create good and sustainable solutions (Choo et al., 2007a). Various steps in the method provide a rational and systematic way to understand the problems and discover solutions, and thus the method guides the flow of the project (Pande et al., 2000). Further, the use of tools promotes understanding of the problem correctly (Goh and Xi, 2004). It also helps in analyzing problems and ensures rationality in problem-solving through root-cause analysis.

Root-cause analysis brings out causal factors that provide an explanation of the problem. Discovering and quantifying these causal relationships lead to knowledge creation (De Mast and Bisgaard, 2007). The DMAIC method in essence is Walter Shewart's Plan-Do-Check-Act cycle, which provides avenues for the team to learn by deductive-inductive iteration (Box, 1997) and hence learning behaviours. An integration of tools and systematic steps in Method provide a logical flow of using tools that help in problem solving and create knowledge (Antony et al., 2008). In this research, the researcher's aim was to investigate how the degree of adherence to the method impacted project performance through learning behaviours. The scale items for the level of adherence to the method were adapted from the existing Six Sigma literature (Choo et al., 2007b; Linderman et al., 2006):

1. The project team strictly followed the sequence of the Method
2. Each step in DMAIC was faithfully completed
3. This team frequently used Six Sigma tools to analyze data and information
4. Regular project review was conducted during the project

Psychological safety

Six Sigma problem-solving requires knowledge sharing among team members (Anand et al., 20010; Linderman et al., 2010). Researchers have argued that a team-based initiatives aimed at knowledge sharing are more likely to succeed in knowledge transfer in an environment that is perceived to be psychologically safe (Edmondson, 1999; Zellmer-Bruhn and Gibson, 2006; Tucker, 2007). Inside psychologically safe atmosphere, members would feel comfortable in sharing knowledge. Psychological safety is an important construct in team learning that is defined as 'shared belief that the team is safe for interpersonal risk taking" (Edmondson, 1999, p. 354). Psychological safety should increase an employee's motivation to share knowledge and hence the team learning behaviours. Team psychological safety shapes the process of people engaging in knowledge transfer among team members (Edmondson, 1999). A psychologically safe atmosphere makes a member feel safe to risk taking without the fear of negative consequences and hence freely engages himself in learning and knowledge transfer. All items for team psychological safety and performance are adapted from validated measures from past studies. The scale for psychological safety measured the climate of the team characterized by members' feeling safe and comfortable with each other. The three items used were adapted from Edmondson's team psychological safety construct (1999). These items captured team interactions characterized by information and knowledge sharing, open discussions and valuing individual skills and knowledge

1. Members were able to discuss problems and tough issues openly
2. Members of the team accepted each other's differences
3. Working with members of this team, my unique skills and talents were valued and utilized
4. No one in the team deliberately acted in a way that undermined my efforts

Challenging goals

A challenging goal in Six Sigma projects involves setting stretch targets that are beyond the member's current abilities. They are hardly attainable unless the necessary knowledge required to solve the problem is acquired. The team members will find it difficult to reach the goal, and it would be challenging for the team to attain that goal. The team needs to expend more efforts in order to reach the goal. This measure captures the team perception of the project as being challenging and difficult and focuses towards customer requirements. It captures the degree of challenge in the goal set for the project team and goal specificity. The items are adapted from a study by Linderman et al. (2006).

1. We found it difficult to achieve the project goals
2. The project goals were challenging to us
3. The project goal was specific and clear
4. The project goal was derived from the voice of the customer

Knowledge

Challenging goals can prompt exploratory learning through experimentation, innovation and broad searching as organizational actors seek new or varied approaches to reach the target identified (Sitkin et al., 2011). These lead to new ideas, improved understanding, and enhanced capability of the team (Vera and Crossan, 2003; Choo et al., 2007b). In this process, Six Sigma project team tries to make use of various new tools and techniques to solve the problem that enhances their skills in using these tools and techniques. The scale of knowledge measures the degree of enhanced understanding and capability enhancement to the team, idea generation by the team and their learning of new tools and techniques. These measures were adapted from Six Sigma literature (Choo et al., 2007b) and Knowledge management literature (Roth and Jackson, 1955).

1. The team generated many ideas while doing the project
2. Doing this project enhanced team's abilities and knowledge
3. The solutions found in this project were clearly unique and innovative to the company
4. We have learned new tools and techniques of Six Sigma

Project leader

Project leader's knowledge building role is operationalized by the following fo items that capture how the leader develops technical expertise within the team, advances on technical isues, monitors the quality of the teams' work, enhances team's knowledge, brings the foucs of the team to the project objective, provides constructive feedback that enhance team's understanding of the problem. The items are adopted from Bain et al. (2005) and Edmondson (1999).

1. Project leader provided constructive feedback
2. Project leader helped the team to focus toward the objective of the project
3. Project leader guided the team to select the optimal solution
4. Project leader initiated meetings to discuss team's progress

Project performance

Each Six Sigma project will have different objectives, such as cycle time reduction, cost reduction, efficiency improvement, process capability enhancement in terms of Sigma level improvement, customer satisfaction improvement, and rejection level reduction. Different project objectives warrant different approaches for defining success criteria than the one usually found in the literature for assessing and comparing project performance. Project performance is multi-dimensional and Shenhar et al. (2002) arrange project performance into three dimensions: (1) meeting project goals (technical and operational performance of the final project outcome and meeting the schedule and budget goal); (2) benefit and impact of the project outcome on the customer; and (3) benefit to the organization (commercial success, the extent to which the project creates new opportunities and financial benefits). The scale items need to measure the extent to which the customer satisfaction, cost-benefits and strategic impact of the organizations are achieved in each project. Similar operationalization was used in earlier studies (Anand et al., 2010; Choo, 2011; Choo et al., 2007; Linderman et al., 2006). All four items of the scale were adapted from Linderman et al. (2006) and used in Choo et al. (2007b), and the items captured the differential success of Six Sigma process improvement projects. To measure and compare project performance across all project types, the respondents were asked to tick the levels (between 1 and 7) at which teams achieved the desired results against the objectives of the project. These items measured the improvement results from each project.

1. We met or exceeded customers’ expectations in this project
2. The cost savings or strategic impact of the project were significant
3. The team had superb results with the project
4. The project was effective in improving the process or product

Other questions

The following items were also included in the questionnaire:

- Years of experience in Six Sigma projects
- Number of projects completed by the respondents so far

- Nature of the project (manufacturing, administrative or others)
- Project goal
- Number of members of the team
- Project duration
- Whether the project was completed within the scheduled time

Finally, meta-analysis of Churchill and Peter (1984, p. 365) have found that the type of scales (e.g. Likert, semantic differential, and rating scale with verbal anchors) has no impact on the reliability of measures, implying that there is minimal impact of the scale type on the psychometric property of the measure. Thus, a 7-point Likert scale is used for all variables in this research similar to some of the existing research in Six Sigma (Anand et al., 2010; Choo et al., 2007b; Linderman et al., 2006).

5.2.2.3 Pre-testing of questionnaire

In order to examine how questions actually work in practice and identify how the respondents are likely to respond, a pilot survey was conducted with 15 Six Sigma Black Belts and 5 project team members from 5 Six Sigma organizations, different from the survey organization. These leaders had extensive experience in carrying out Six Sigma projects and participated in Six Sigma deployment in their respective organizations and the members had participated in more than three projects. The pilot tests helped investigate the following characteristics of the survey questions and subsequently modifying and refining them: (1) Clarity: Is the question clear and easy? Questions void of grammatical ambiguity which can produce differing interpretations across respondents, free from excessive complexity, and free from vague concepts and unfamiliar terms, etc. (2) Content: Does the question make sense? Free from faulty presupposition, and (3) Is it appropriate? Accordingly, some of the scale items underwent modifications.

5.2.3 Data collection

In order to increase the triangulation of data collection, it was decided to get responses from both the project leaders and members. The research aimed to get responses from the project leader and at least two team members from each project similar to other related studies in Six Sigma (Choo et al., 2007b; Linderman et al., 2006). Another objective of using multiple respondents for the survey is to reduce *common-method bias*, which is a problem that arises from the use of a single respondent for providing both independent and dependent variable data. This may likely create correlations between these variables because of the common informant. Multiple respondents help mitigate this issue.

The researcher also wanted to reduce the number of questions for the members, as a shorter survey has a greater chance of getting a higher response rate. Especially, in a web based survey, it is even more important to have a shorter survey. In the web environment, respondents tend to give up easily if they find that the survey is too long.

Through email notification from the deployment champion/director of Six Sigma, the project leaders and members from each selected project were invited to participate in this survey. Individual invitation letters were sent subsequently through emails with a link to the questionnaire for all selected participants. In order to get the responses for the same project from both leaders and members, the information about the project was mentioned in the covering letter so that the replies are for the same projects. A follow-up reminder and thank you emails were sent every week until a satisfactory response level was reached in 3 weeks.

5.2.3.1 Response rate

The responses from each project were considered full (full set of response), if the responses are received from its project leader and at least two members from the project. 52 sets of completed and usable responses from MFG1 and 50 sets of responses from MFG2 were returned after two email reminders. This resulted in a response rate of 51.5% (calculated based on actual usable response sets to the total number of questionnaires set sent), which is considered as an above average response rate (Anand et al. 2010). It is to be noted that a low response rate trend was evident in the literature and this trend was prevalent across the globe (Ahmed et al., 2004; Sousa et al., 2006; Anderson and Sohal, 1999). Overall, the total number of responses received (project leaders and members put together) were 324 against the targeted sample of 551 respondents. This corresponds to 58.8%. The details of the number of projects selected for the survey and the responses obtained are given in Table 5.8.

It is also equally important to study the non-responses to identify whether they are different from the respondents, leading to biases in the result (Fowler, 2002; Forza, 2002), as non-respondents can limit the generalisability of the results. Ten people from the non-respondent list of the each participating companies were randomly selected and contacted by telephone/email to identify the reasons for their non-participation. Some key questions were asked to identify any discernable pattern in their responses. Most of them did not participate due to work pressure and limited time to respond to the survey, and none of them had any objections about the content of the questionnaire.

Table 5.8 Sample Projects and response rate

	MFG1	MFG2	Total
Total projects targeted	110	88	198
Usable Responses obtained	52	50	102
Response rate	47.3%	56.8%	51.5%
Total members targeted	300	251	551
Usable Response obtained	158	166	324
Response rate	52.6%	66.1%	58.8%

An estimate of non-response bias was calculated by testing the difference in variables between early and late respondents (Lambert and Harrington, 1990). A two-sample t-test was performed on the average score of all variables. No siginificant differences were found between early and late respondents.

Responses on dimensions of resources, knowing-what, knowing-how and performance were collected from the project leaders, and responses on psychological safety –a team-level construct, challenging goal and method were collected from both project leaders and team members (minimum of two team members for each project), and leader behaviour from members only, as depicted in Table 5.9.

Project leaders are trained Black Belts or Green Belts who have expertise in tools and techniques and problem-solving methods such as DMAIC. Leaders use various practices to gather and synthesize the knowledge of team members toward achieving project outcomes (Arumugam, 2013, 2014; Anand et al., 2010); they are in a good position to provide information about knowledge creation practices used by the team during the project execution, resources made available, project outcomes, and other team level variables. The study looked into the completed projects only.

Table 5.9 Survey responses

Factors	**Leader**	**Member**
Resources	√	
Psychological safety	√	√
Challenging goal	√	√
Method	√	√
Leader behaviour		√
Knowing-what	√	
Knowing-how	√	
Performance	√	

5.3 Case study research

Case study research has consistently been one of the most powerful research methods in operations management, particularly in the development of new theory (Voss et al., 2002). Case studies are empirical investigations to inquire a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not really evident (Yin, 2009). A case study typically uses multiple methods and tools for data collection from a number of entities by a direct observer(s) in a single, natural setting that considers temporal and contextual aspects of the contemporary phenomenon under study, but without experimental controls, or manipulations (Meredith, 1998).

The case study inquiry

- copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- benefits from the prior development of theoretical propositions to guide data collection and analysis (Yin, 2009:18)

The case study looks in depth at one, or a small number of, organizations, events or individuals, over time. Although the case method conforms to positivist paradigm, the method can be designed in ways consistent to constructionist perspective.

Advocates of single case studies come from constructionist epistemology and those of multiple cases usually fit with a more positivist epistemology. If the case study is done with rigor, it may create the same degree of validity as more positivist studies. Table 5.10 shows some of the main distinctions in the use and application of the case method along with the epistemological continuum.

Table 5.10 Key features of case methods informed by different epistemologies (Adapted from Easterby-Smith et al., 2012)

	Positivist	Critical realist	Constructionist
Design	Prior	Flexible	Emergent
Sample	Up to 30	4 to 10	1 or more
Analysis	Cross-case	Both	Within case
Theory	Testing	Generation	Action

5.3.1 When to use case study

Case studies are the preferred method of research when '*how*' and '*why*' research questions are being investigated, when the researcher has slight control over events, and when the focus is on a contemporary phenomenon surrounded by some real-life context (Yin, 2009). The method lends itself to early, exploratory investigations where the variables are still unknown, and the phenomenon not at all understood. Leonard-Barton (1990) described a case study as "a history of the past and current phenomenon, drawn from multiple sources of evidence. It can include data from direct observations and systematic interviewing as well as from public and private archives. In fact, any fact relevant to the stream of events describing the phenomenon is a potential datum in a case study, since context is important" (quoted by Voss et al., 2002). The case study is also a useful strategy in the early phase of research, where there may be no previous work for guidance (Meredith et al., 1989) or where existing theories seems inadequate (Eisenhardt, 1989). Denzin and Lincoln (2003) suggest that rich descriptions of the social world are valuable, and this rich picture is important to understand social world issues. Eisenhardt and Graebner (2007: 25) suggest that "a careful justification of theory building, theoretical sampling of cases, interviews that limit informant bias, rich presentation of evidence in tables and appendices, and a clear statement of theoretical arguments" are important elements in case study research which bring objectivity and possibly generalizability.

5.3.2 Types of case study

Depending on the intentions of the research, case research can be differentiated as *exploration, explanatory, theory building, theory testing and theory extension/refinement* (Voss et al., 2002; Yin, 2009).

Exploration

Exploration case study is generally adopted in the early stages of many research programs. It helps to develop research ideas and questions. (Frohich 1998) has observed that many doctoral theses begin with one or more case studies in order to generate a list of research questions that are worth pursuing further (quoted by Voss et al., 2002).

Explanatory

Explanatory type of research, the researcher tries to investigate whether event 'x' leads to event 'y'. Here the researcher's interest is to investigate the causality between dependent variables (y) and independent variables (x). *How* and *why* types of research questions are investigated in this type of case research. This research calls for temporal studies since causal linkage requires studies that are traced over time.

Theory building

Theory building stream of research employs case research predominantly. By theory, we mean ''an ordered set of assertions about a generic behaviour or structure assumed to hold throughout a significant broad range of specific instances'' (Sutherland, 1975: 9). Theory can be considered to be made up of four components: definitions of terms or variables, a domain-the exact setting in which the theory can be applied, a set of relationships and specific predictions (Wacker, 1998). In theory-building case research, the researcher goes through observations and classifications cycle in order to not only proof seeking but also searching for anomaly between empirical work and existing theory (Eisenhardt, 1989; Whetton, 1989).

Theory testing

For theory test application, case studies find limited application, and generally they are used in conjunction with survey-based research. The main application is in strategy implementation research discipline (Voss et al., 2002).

Theory extension/refinement

Case studies can also be used as a follow-up to survey research in an attempt to examine more deeply and validate previous empirical results (Voss et al., 2002).

In the present research, the researcher used a case study research (chapter 8) to examine more deeply and validate the results obtained from the survey research.

McCutcheon and Meredith (1993) commented on the suitability of the case study approach to study unfamiliar situations, where there exists a little theoretical background on the subject of interest. In this research, there exists very little evidence in the literature on learning behaviours and their impacts and antecedents in Six Sigma projects. By conducting case studies in the second phase of the research, the researcher is trying to corroborate the findings of the survey research as well as getting the new themes emerge if any.

5.3.3. Main activities in case study research

Eisenhardt (1989) proposes a framework for the process of theory building from case study research which is shown in Table 5.11 The framework suggests a process that starts with the definition of research questions and arrives at a closure in the research. Each step in theory building also contributes to research quality by strengthening the constructs, evidence, theory and internal/external validity.

As the case study research is the part of the mixed methods research, several validation strategies specific to sequential ‘‘*Quantitative* → *Qualitative*’’ mixed methods design were also followed in this research (Creswell, & Plano Clark, 2011; Ivankova, 2014; Teddlie & Tashakkori, 2009):

- Adopting systematic procedures in selecting case projects, elaborating on unexpected quantitative results
- Conducting follow-up quantitative analysis relating to the emergence themes/phenomena found in qualitative analysis

Thus, this research observed interaction between qualitative and quantitative study strands. These will be explained in chapter 8 & 9.

Table 5.11 Process of theory building from Case Study Research (Eisenhardt, 1989)

Step	**Activity**	**Reason**	**Where in this research?**
Getting started	Definitions of research questions Possibly a priori construct measures	Focuses efforts Provides better grounding of construct measures	Ch 2, 3
	Neither theory nor hypotheses	Retains theoretical flexibility	
Selecting cases	Specified population	Constraints extraneous variation and sharpens external validity	Ch 5
	Theoretical, not random sampling	Focuses efforts on theoretically useful cases – i.e. those that replicate or extend theory by filling conceptual categories	
Crafting Instruments and protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence Synergistic view of the evidence	Ch 5
	Qualitative and quantitative data combined Multiple investigations	Fosters divergent perspectives and strengthens grounding	
Entering the field	Overlap data collection and analysis, including field notes Flexible and opportunistic data collection methods	Speeds analyses and reveals helpful adjustments to data collection Allows researchers to take advantage of emergent themes and unique case features	Ch 8
Analyzing data	Within-case analysis	Gain familiarity with data and preliminary theory generation	Ch 8
	Cross-case pattern search using divergent techniques	Forces researchers to look beyond initial impressions and see the evidence through multiple lenses	
Shapping hypotheses	Iterative tabulation of evidence for each construct Replication, not sampling, logic across cases Search evidence for 'why' behind relationships	Sharpens construct definition, validity and measurability Confirms extends and sharpens theory Builds internal validity	Ch 8
Enfolding literature	Comparison with conflicting literature Comparison with similar literature	Builds internal validity, raises theoretical debate and sharpens construct definitions Sharpens generalizability and raises theoretical level	Ch 8
Reaching closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small	Ch 8

Note: Ch refers to Chapter number of this dissertation

The following four components of case study research design are especially important prior to data collection, data presenting and data analysis (Eisenhardt, 1989; Voss et al., 2002; Yin, 2003b).

- Developing the research framework, constructs, and questions
- Choosing case study type
- Selecting cases
- Developing research instruments and protocols

These four elements will be discussed in the following sections, and the rest of the components of case study research (data collection, data presenting and analysis and reaching closure) will be discussed in chapter 8.

5.3.3.1 Developing the research framework, constructs and questions

Development of a conceptual framework (theoretical proposition) will benefit the case study toward leading the research. It helps to assess and refine the research goal, develop realistic and relevant research questions, and select appropriate methods (Yin, 2009; Maxwell, 2005). A conceptual framework is primarily a conception or model of what is out there that a researcher plans to study and of what is going on with these things and why-a tentative theory of the phenomenon being inquired (Maxwell, 2005). The conceptual framework is a key part of the research design, as it informs and supports his research. The framework encompasses the system of concepts, assumptions, expectations, beliefs and theories (Miles and Huberman, 1994). Miles and Huberman (1994) define it as a ‘‘visual or written product, one that explains either graphically or in a narrative form, the main things to be studied-the key factors, concepts, or variables- and the presumed relationships among them’’ (p. 18). The framework is a tentative theory of the phenomenon and its primary function is to help the researcher to assess and refine goals, develop realistic and relevant research questions, select appropriate methods, and identify potential validity threats to the conclusion, and it even justifies the research (Maxwell, 2005). In fact, the research problem is a part of the framework.

A conceptual framework is something not found but developed or constructed from the existing knowledge on the topic (Maxwell, 2005). Although it incorporates knowledge borrowed from various sources, structure and overall coherence are something a researcher builds, not something that exist already. Maxwell stated that there are four primary sources that can be used to construct a framework:

- Researcher's experiential knowledge
- Existing theory and research
- Pilot and exploratory research
- Thought experiments

Incorporation of experience in the research has gained wide theoretical and philosophical support (example, Denzin & Lincoln, 2000; Jansen & Peshkin, 1992). Researcher's technical knowledge, his research background, and personal experience should not be ignored as they may provide a valid clue to formulate a potential framework (Strauss, 1987). However, the researcher should not allow to be swept away and overwhelmed by it, rather he or she raises it to consciousness and uses it as part of the inquiry process (Reason, 1994).

The primary function of a theory is to provide a model or map of why the world is the way it is (Strauss, 1995). By not using existing theories, one might miss the insights that the existing theories can provide. At the same time, it can prevent the researcher from seeing events and relationships that don't fit the theory. A key strategy could be to develop or borrow theories, continuously test them, looking for discrepant data and alternative ways of making sense of the data. Similarly, past research can provide a justification for the research- to show how one's work will address an important need or unanswered question and thereby help develop a conceptual framework. Prior research can inform one's decisions about methods, suggesting any alternative approaches or revealing potential problems and their solutions. It can also help generate theory.

An important use of the pilot study in case research is to develop an understanding of the concepts and theories held by the people the researcher is studying. It also provide with an understanding of the meaning that these phenomena and events have for the people who are involved in them, and the perspectives that inform their actions (Maxwell, 2004a; Menzel, 1978).

Thought experiments are regularly used in economics, but rarely used in social science research. Thought experiments help think about how to support or disprove an observation through plausible explanations. They generally draw on both the theory and experience to answer ‘what if’ questions. It can also both generate new theoretical models and insights and test one's current theory for problems (Maxwell, 2005)

Research questions and a conceptual framework for the research were developed based on the in-depth review of the literature in chapter 2 and 3 and using his experiential knowledge.

5.3.3.2 Choosing case study type: multiple cases

A single case study design is a common design for doing case studies and is justifiable under certain conditions such as (1) case represents a critical test of existing theory, (2) a rare and unique circumstance, or (3) typical case, (4) a case serves a revelatory or longitudinal purpose (Yin, 2009). Single in-depth case studies are often used in longitudinal research (Voss et al., 2002; Narasimhan and Jayaraman, 1998). Single case limits the generalizability of the conclusions as the data from a single case induce risks in misjudging a single event, and exaggerate the finding. Multiple case study designs have increased in frequency in recent years, and the evidence from multiple cases is often considered more compelling and more robust (Herriott and Firestone, 1983). Multiple case evidence often helps guard against observer bias (Voss et al., 2002).

This research follows Yin and Eisenhardt’s approach and adopts a *multiple case study approach* because multiple-case logic produces robust results and contributes to theory through rigorous concepts and constructs, triangulation, replication logic and pattern searching (Eisenhardt, 1989; Yin, 2009). Multiple case studies cover both the phenomenon of interest and its context, yielding a large number of potentially relevant variables (Yin, 1981; Eisenhardt, 1989; Yin, 2003a; Yin, 2003b; Eisenhardt & Graebner, 2007).

5.3.3.3 Selecting case projects

As explained earlier, the unit of analysis is Six Sigma project. The primary objective of this case study research is to identify learning practices and their potential antecedents and performance consequences of Six Sigma projects from the interview outcome. As the case study research is the part of the mixed method research, the researcher followed a systematic procedure to select the projects and thus the participants (Creswell, & Plano Clark, 2011; Ivankova, 2014; Teddlie & Tashakkori,

2009) This is to ensure that the mixed method research provides a credible and valid research findings. In mixed method study, one study builds on another and hence, the quality of the inferences produced in one study may markedly affect the quality of the inferences generated in another study (Creswell & Plano Clark, 2011; Teddlie & Tashakkori, 2009). Selection of the cases for the qualitative study was done systematically by following the criteria (Creswell, & Plano Clark, 2011; Ivankova, 2014; Teddlie & Tashakkori, 2009): Only those projects which have participated in the survey; typical, extreme or unique projects; projects which have reported extreme score on dependent variables; projects which have produced unexpected results (performance, extended project duration, etc.); and wide project topics. These criteria would help to elaborate any unexpected results from the survey research and allow any new themes to emerge. The following were also considered while selecting the projects: cases (projects) need to be interesting, to provide inspiration (case tells the story and concept emerges) and need to be illustrative (Eisenhardt & Graebner, 2007; Siggelkow, 2007; Stake, (1995: xi). The sample case could be one of the extreme cases, heterogeneous, homogeneous, critical and typical case (Saunders et al., 2000; Silverman, 2000). Yin (2009) asserts that each case must be carefully selected so that it either predicts similar results (literal replication) or predicts contrasting results but for anticipated reasons (theoretical replication). In order to get heterogeneity in projects, sample projects were selected from broad functions such as manufacturing, finance, maintenance, and purchase. Case study data collected in such diverse contexts tend to provide more opportunities for checking alternative explanations and conducting multiple comparisons as various themes emerge.

Going through the projects from the survey data, their various responses, and project database, the researcher along with the representatives from the participating organizations selected totally five projects (cases), three from MFG1and two from MFG2. Of the five, *three projects are reported to have obtained best performances, and two have typical performances.* The projects showed variation in the project goal, team composition, leadership characteristics, project duration, project complexity, affected by things that are beyond the scope of the project teams and project performance. These helped maximize the contrasts in the sample, and increase the validity through “deliberate sampling for heterogeneity” (Cook and

Campbell, 1979, p. 75). Thus, the sampling used in the survey research is *purposive sampling*. The researcher has a clear idea of what sample units are needed to collect data that can answer the research questions. In purposive sampling, potential samples are approached, and those samples that satisfy the criteria are used for the survey.

5.3.3.4 Research instrument and protocol

Typically the primary sources of information for case study research are interviews, either a structured or semi-structured, often backed by interactions. Other sources are informal conversations, meetings and events, surveys administered within the organizations, objective data including archival sources (Voss et al., 2002).

This research aims to answer research questions to unfold various learning behaviours, antecedents (both organizational and project level) and performance consequences and to let new theme emerge from the case study. Therefore, the researcher needs to get information from (1) persons from the higher hierarchy of organization who will be in a better position to provide information regarding various organizational factors that affect learning and project performance; (2) project leaders who facilitate learning and knowledge in project teams, and who themselves learn in projects can give information on team learning, and as project leaders they are knowledgeable to provide information about various organizational factors and their influence on the project; and (3) team members whose interpretations and viewpoints provide insights into their own learning behaviours and project execution. Yin suggests that the essential tactic is to get multiple sources of evidence, with data needing to converge in a triangulation fashion (Yin, 2009). Further, the multiple viewpoints from more team members and leaders would reduce subjectivity and bias. Hence, it was decided to have multiple respondents in this case study research, consisting of senior management team, project leader, and team members. Since, getting all the team members from each project team is practically difficult, it was decided to aim for at least two members of each project along with the project leader. As the information sought from each set of people is varied, it was decided to have three different sets of semi-structured questionnaires targeted to each category of people covering various aspects of information sought.

5.3.3.4.1 Case study protocol

The interview is one of the most widely used methods in qualitative research (Bryman et al., 2008). Interviewing, the transcription of interviews, and the analysis of transcripts are time consuming, but considered to be the best method of gathering large amount of in-depth data in a short time span while conducting a case study (Marshal and Rossman, 1995; Easterby-Smith et al., 2012; Yin, 2009). The interview can be either a structured one or a semi-structured one. In a semi-structured interview, the researcher usually has a list of questions or specific topics to be covered and is often referred to as interview guide. The Different features of the two interview methods are displayed in Table 5.12.

In this research, data collection method adopted was interviews, often combined with other data collection methods such as archives and observations. Observation as a data collection method has been widely used in almost all social research. Direct observation is done through one or more of the observer's senses to collect the relevant data. It also involves the use of careful, methodical plans for the selection, recording and encoding of that set of behaviour, settings or actions, which is consistent with empirical objectives (Weick, 1968). The premise in a social research setting is that humankind can observe almost all social phenomena.

Table 5.12 Interview types (Yin, 2009)

Structured interviews	**Semi-structured/unstructured interviews**
Standardized pre-prepared questions	Flexible framework to open up new lines of inquiry
Easier to time and control the interview	More time-consuming and chances to digress away from the topic of interest
Suitable for less experienced interviewer	Need for an experienced interviewer who can hold an interesting conversation during the interview to obtain more data
Comparable data	Can be difficult to compare the results
Difficult to follow-up point of interest, or emerging themes	New points or emerging themes can be followed up

In order to enhance the validity and reliability of the research, the researcher used a well-defined case study protocol that describes explicit and well-planned field procedures encompassing guidelines during field visit for the data collection (Yin, 2009).

A case study protocol generally comprises the following sections (Yin, 2009, 81):

- An overview of the case study project (objectives, case study issues, and relevant readings about the topic being investigated)
- Field procedures (presentation of credentials, access to the case study sites, sources of data, and procedural reminders)
- Case study questions (specific questions that the researcher must keep in mind in collecting data, ‘table shells’ for specific arrays of data and the potential sources of information for answering each question)
- A guide for the case study report (outline, format for the data, use and presentation of other documentation, and bibliographical information).

5.3.3.4.2 Case study questions

Case study questions must reflect the actual line of inquiry. It must remind the interviewer regarding the information that needs to be collected and why. The overall purpose of the questions is to keep the investigator on track as data collection proceeds. Questions for this case study research are designed in such a way that they are directly linked to research questions and conceptual framework, *but not directly related to learning behaviour*. Research questions formulate what the researcher wants to understand; his interview questions are what he asks people in order to gain that understanding (Maxwell, 2005). The aim of these questions is to clarify all activities that the team carried out to make the project successful. The development of good interview questions requires creativity and insight and depends on how the interview questions will actually work in practice. Salient features of the interview questionnaires for the research are given below.

- Unit of analysis for the research is a project team. A separate set of questions was developed for Six Sigma deployment champion/senior executive, project leader, and members. The questions for deployment champions and senior executives were focused to get answers on Six Sigma deployment, deployment history, general resources made available to projects, how far the senior management team extended support for project execution, and what level of support were provided to the project team in getting outside experts for the projects and general overview of the overall project success.

- The questions for team leaders were formulated to get information on how he facilitated project execution; through his perspectives, what were the activities team members carried out that helped to succeed projects and his own activities that helped enhance the project performance. In addition, for a leader, questions were also posed how he supported the team in problem solving and toward improving team's capability. The leader was also asked to narrate contextual factors or events that impacted/inhibited project success. Other questions to the leader related to how his role in focusing the project objective, how he motivated the team, how he acted during a difficult period, and how his relationship with management to get support in terms of resources. These general questions also allowed the researcher to get many examples of how project leaders facilitated team learning and team's learning behaviour.
- Team members were asked about leader's activities toward project execution, their own activities in enhancing their capability, how they perceive about the impact of management support for project success. Questions were asked to narrate any specific actions that helped getting new insights about the problems they were investigating.
- Interview questions for team leaders and members asked them to describe the general features of the project, goal, team compositions, the nature of the project and the problem, the nature of the tasks, how team organized its work, challenges and other unexpected things/events that the team had to face, and how they went about overcoming and progressing the project through DMAIC phases.
- *No direct questions were asked about learning*, but only general questions as mentioned earlier. Answers to these general questions brought out examples and events of various learning activities they undertook during project execution.

Feedback from academic experts and Six Sigma experts (the researcher's colleagues) were obtained on how they think the questions will work. A pilot test was subsequently conducted with three project leaders and two members from projects other than the sample projects from MFG1. The pilot test helped identify if the questions worked as intended and led to adding some questions and revision in some of the existing questions. Overall, the pilot test contributed to making the interview questionnaire more effective in bringing out the intended data for the research. Appendix III shows case study protocol and Appendix IIIA shows the interview guidelines used in this research.

Developing the research framework, research questions, hypotheses, and constructs were explained in chapter 3 after an in-depth review of the literature and gap analysis in chapter 2 and 3. Chapter 8 will explain aspects such as, ***data collection, analysis,*** *and* ***reaching closure.*** Multiple sources of data, including interviews, training materials, and other related documents were collected to triangulate the findings. The primary source of data, however, came from the interviews. There are a total of 19 face-to-face semi-structured interviews conducted on-site with interview length from 1 hour to 90 minutes.

5.4 Criteria for Assessing the Quality of Research

A key justification for a robust research is that it yields results that are more accurate and believable (Easterby-Smith et al., 2012). The results are nothing but the answers to the research questions that the researcher aims to obtain by his research process. The quality of the result, and hence the quality of the research depends on the quality of the research processes that the researcher carries out. The researcher will focus on the four quality criteria derived from the literature (Miles and Huberman, 1994; Stake, 1995; Meredith, 1998; Easterby-Smith *et al*., 2002; Voss et al., 2002; Yin, 2009; Ates, 2008) which are discussed here. These research quality criteria will guide the research methodology choices and data analysis and will ensure a reliable and systematic process to conduct the studies In addition, the assessment will also be done on the contribution of the research to both theory/knowledge and practice.

This section will explain the research quality criteria which will guide the research methodology carried out in this research and will ensure a reliable, consistent and a systemic process to conduct research. The evaluation of how this research meets the quality criteria together with possible limitations and further work will be discussed in Chapter 9.

4-key criteria to ensure quality in this research:

- Construct Validity
- Internal Validity (for case study) / Content Validity (for surveys)
- External Validity/Generalisability
- Reliability

5.4.1 Validity, reliability, and generalizability

Validity, reliability and generalizability mean different to different research traditions. Table 5.13 summarizes these terms from the philosophical viewpoints.

Table 5.13 Validity, reliability, and generalizability (Adapted from Easterby-Smith et al., 2012:71)

	Viewpoint		
	Positivist	Critical Realist	Strong Constructionist
Validity	Do the measures correspond closely to reality?	Have a sufficient number of perspectives been included?	Does the study clearly gain access to the experiences of those in the research settings?
Reliability	Will the measures yield the same results on different occasions (assuming no real change in what is to be measured)?	Will similar observations be made by different researchers on different occasions?	Is there transparency in how sense was made from the raw data?
Generalizability	What is the probability that the patterns observed/findings in a study will also be present in the wider population from which the sample is drawn?	How likely is it that ideas and theories generated in one setting will also apply in other settings?	Do the concepts and constructs derived from this study have any relevance to other settings?

5.4.1.1 Validity, reliability, and generalizability of survey research

Data collection for the survey research is done through questionnaires which use measurement instrument to measure the constructs or concepts. Each concept of the study is measured through a set of indicators or statements that stand for the concept. Respondents are asked to indicate their level of agreement or disagreement on a scale ranging from ‘Yes, I strongly agree’ to ‘No, I strongly disagree’. When measurements are unreliable or invalid, analysis of the collected data can lead to incorrect inference and wrong conclusions. A thorough measurement analysis for validity and reliability of the instrument using statistical analysis is essential to provide confidence that the empirical findings accurately reflect the proposed concepts. Several approaches to establishing validity are to be followed to deal with content validity, construct validity and criterion- related validity.

Content validity represents the adequacy with which a specific domain of content has been sampled (Nunnally and Bernstein, 1994). It is required to establish that the instrument is truly a comprehensive measure of the construct being measured. Nunnally described two standards for ensuring content validity: (1) the instrument contains a representative collection of items and (2) ‘‘sensible’’ methods of test construction are used. Comprehensive literature review can provide a representative collection of items, and further interviewing with experts and practitioners and pilot test can help refine the measurement scale items (Fynn et al., 1994).

Construct validity is the extent to which the researcher establishes correct operational measures for the concepts being studied. A scale is said to have construct validity if it measures the concept that it is intended to measure. Only indirect inference can be made on the construct validity by empirical investigation (Flynn et al., 1994). Construct validity can be established using principal components factor analysis (PCA). Construct validity has three components: *unidimensionality*, *convergent validity*, and *discriminant validity*. In a unidimensional construct, all items measure a single concept. An instrument has convergent validity if the correlations between measures of the same construct using different methods are high (Crocker and Algina, 1986). The discriminant validity is the degree to which measures of various factors are discrete (Bagozzi and Yin, 1991). An instrument has discriminant validity if the correlations between measures of different factors using the same method of measurement are lower than the reliability coefficients (Crocker and Algina, 1986). Assessing the validity requires the estimation of the average variance extracted (AVE) for each construct. AVE is the mean variance extracted for items loaded onto a construct and indicates convergence (Hair, et al., 2010). AVE is the total of the squared standardized factor loadings (or standardized regression weights in AMOS) divided by the number of items. Established heuristics (Fornell & Larcker, 1981; Hair, et al., 2010) recommend that this should be ideally no less *than 0.5 indicating adequate convergence and that there is not more error in the items* than there is explained by the construct measures. Finally the most rigorous test for discriminant validity (the extent to which one construct is distinct from another) is calculated by comparing the AVE values for the chosen constructs with the square of the correlation between the same constructs (Hair, et al., 2010) the AVE should be greater than the square of any correlation to achieve discriminant validity.

Criterion-related validity is a measure of how well scales representing various variables or factors are related to measures of the dependent variable. It means the extent to which we can establish a causal relationship, whereby certain conditions are shown to lead to other conditions.

Scholars suggest the use of summated scales from the past research with established validity and reliability to counteract with the difficulty of establishing validity and reliability in the new research (Flynn et al., 1994).

Reliability (internal consistency) of the instrument refers to the degree of dependability, consistency or stability of the scale. If all items of the scale are internally consistent, meaning that they explain the majority of the variation in the construct, then the scale is said to be reliable. The reliability of the scale is estimated by calculating Cronbach's α (Cronbach, 1951). An acceptable reliability value is 0.70 or more (Nunnally and Bernstein, 1994).

G*eneralizability/external validity* refers to extending research results, conclusions that are based on a study of a single population to a wider population.

Table 5.14 shows some of the tactics that can overcome the above challenges about reliability and validity in survey research. Criteria addressed in the survey research are mentioned in the table. Chapter 6 and 7 will explain how they are executed, and the evaluation of the research on these criteria will be explained in chapter 9.

Table 5.14 Summary of research quality criteria in survey research (Nunnally, and Bernstein, 1994; Flynn et al. 1994; Forza, 2002; Malhotra and Grover, 1998)

Research quality criteria		**How these criteria are addressed in this research**
Construct validity	• Ability of the scales to measure what it sets out to measure • The extent to which the items in a scale all measure the same concept, and the scale does not contain items which represent aspects not included in the theoretical concept.	• Unidimensionality: Use Principal components analysis to select factors (check whether any items loaded on more than a factor or concept and if so, the items are removed from the analysis). • Use Confirmatory factor analysis: Check for the convergence between measures of the same construct (convergent validity) and separation between measures of different constructs (discriminant validity). • Estimate average variance extracted for each construct (should be more than 0.5 for convergence). Compare the average values for constructs with the square of the correlations between the same pair of constructs for discriminant validity (AVE should be more than the squared correlation).
Criterion validity	The extent to which the scales are related to external referents	Validity depends on how well the instrument correlates with what it is intended to predict.
Reliability	The consistency of a measure of a concept Only little variation over time in the results obtained .	Reliability was operationalized as internal consistency (Flynn et al., 1994): Degree of inter-correlation among the items that comprise a scale. Cronbach's alpha values are calculated for each scale, and the scales are accepted if the values are above 0.7. Adopt or use existing validated instruments from literature
Internal/content validity	• Measures the extent to which the content of the items in a summated scale truly measures the concept it intends to measure	• Develop a questionnaire based on an in-depth review of the literature • Incorporate the experts' comments • Conduct a field survey (pilot) and modify if necessary

Another potential problem a researcher may encounter in survey research is *common method bias*. The potential for inflated empirical relationships can occur when data for independent variables and dependent variables are collected using the same method or provided by the same respondent. These situations may introduce a response bias that would exaggerate the magnitude of the empirical relationships between variables and hence, the researcher has to take suitable action to avoid this common method/source variance. Multiple sources of data are recommended to overcome this effect. If both the dependent and independent variable data are collected from the same respondent, the statistical test to check for common method bias are recommended (Podsakoff and Organ, 1986).

5.4.1.2 Validity, reliability and generalizability of case study research

In the positivist tradition, internal validity, construct validity, external validity and reliability are commonly used criteria to assess the rigor of field research (Campbell, 1975; Eisenharfdt, 1989; Gilbert et al., 2008; Yin, 2009).

Construct validity

Construct validity refers to the extent to which a study investigates what it claims to investigate, i.e. to the extent to which the procedures adopted in the research lead to an accurate observation of reality (Denzin and Lincoln, 1994). The use of multiple sources of evidence, instead of single sources encourages convergent lines of inquiry that is appropriate for data collection. The triangulation helps adopt different angles from which to look at the same phenomenon. A second tactic suggested is establishing a chain of evidence during data collection, which would allow readers to reconstruct how the researcher went trough his initial research questions to the final conclusions. The third tactic is to have the draft case study report reviewed by key informants for their concurrence (Yin, 2009).

Internal validity

Internal validity in case study research refers to setting up a causal relationship, whereby definite circumstances are exposed to lead to other circumstances, as distinguished from spurious relationships (Yin, 2009), and thus refers to the causal relationships between variables. Yin (2009) suggests applying the following tactics while data analysis to enhance internal validity: pattern matching; explanation building; Address rival explanations; and logic models.

External validity/Generalisability

This quality criterion aims to establish the domain to the research findings that can be generalized so as to ensure credibility. Neither single nor multiple case studies allow for statistical generalization (inferring conclusion about a population). Yin (2009) argues that case studies provide analytical generalization in that it refers to the generalization from empirical observations to theory. The external validity has been a key problem for case study research. Single cases present a weak basis for generalizing. Hence, the replication logic should be applied in order to test and replicate the findings in multiple contexts (Yin, 2009). This should be done at the research design stage itself. Eisenhardt (1989) argues that multiple cases involving 4 to 10 cases may provide a good basis for analytical generalization. A nested approach involving multiple cases from a single organization also will enhance the external validity (Yin, 2009). Clear explanation of the rationale for the case study selection allows the reader to appreciate the researcher's choices (Cook and Campbell, 1979).

Reliability

The research should demonstrate that the data collection procedures can be repeated, with the same results in an auditable way (Yin, 2009). The process that the researcher uses during data analysis should be auditable. And should follow a clear process that another person could adopt (i.e. It is not idiosyncratic); and enabling a subsequent researcher to arrive at the same insights if he or she conducts the study along the same steps again (Denzin and Lincoln, 1994). The purpose of reliability as a research quality criterion is to reduce the level of biases in research. Transparency and replication are the keywords. Transparency can be enhanced through measures such as documentation of research procedures, such as protocol. Replication may be achieved by providing a case study database in which all case study notes, documents and transcripts are deposited so that they can be retrieved for later investigations (Yin, 2009).

Table 5.15 displays these tactics as suggested by Cook and Campbell (1979), Eisenhardt (1989), Yin (2009) and Denzing and Lincoln (1994) in order to tackle some of the above research quality challenges.

5.4.1.3 Contribution to the theory/knowledge and practice

For doctoral thesis, it is necessary to demonstrate that the research provides contributions to theory and knowledge (Easterby-Smith et a., 2012). One of the major expectations is its contribution to knowledge in terms of added value to the existing knowledge. This could be: confirmation of existing theories; extension or refinement of an existing theory; advances in methodology; developments in the application of techniques; generation of hypothesis; generation of grounded theory; and generation of insights (Beech, 2005). Since management research is applied in nature, the applicability of the research findings in practice is considered an important aspect of theory building and theory extension including refinement. The kind of contribution can be in the form of guidance for decision-making on social issues or business problems to policy makers or practitioners.

Table 5.15 Case study tactics (Cook and Campbell, 1979; Eisenhardt, 1989; Yin, 2009; Denzing and Lincoln, 1994)

Tests	**Case study tactics**	**Phase of case study in which tactics occurs**
Construct validity	• Use multiple sources of evidence • Establish a chain of evidence • Have key informants review draft case study report	• Data collection • Data collection • Composition
Internal validity	• Do pattern matching • Do explanation building • Address rival explanations • Use logic models	• Data analysis • Data analysis • Data analysis • Data analysis
External validity	• Use theory in single-case studies • Use replication logic in multiple case studies	• Research design • Research design
Reliability	• Use case study protocol • Develop case study database	• Data collection • Data collection

Table 5.16 summarizes main tactics that will be considered to demonstrate that the research provides valid contributions to theory and practice and offers credible research findings and implications.

Table 5.16 Summary of evaluation of research: Contributions
(Yin 2009; Easterby-Smith et al., 2012; Maxwell, 2005; Ates, 2008)

Research quality criteria	**The research aims**	**Research tactics**
Contribution to theory	What is the added value of what is known already in the literature? What is the theoretical basis? How the findings enfold literature?	• Confirmation of existing theories • Extension of the theory into new areas • Advances in methodology • Developments in the application of techniques • A proof • Disproving a null-hypothesis • Generation of hypothesis • Generation of grounded theory • Generations of insights • Theoretical reflection on practice
Contribution to practice	Are research implications and conclusions acknowledging policy makers or practitioners to help them in decision making into business or social issues?	• Suggestions, implications, etc. • Models, frameworks, road maps, guidelines, workbooks • Normative practices

5.5 Ethical issues

In the context of research, *ethics* refers to the appropriateness of the researcher's behaviour in relation to the rights of those who become the subject of his research or are affected by it (Saunders et al., 2007). In management research, the researcher is dependent on other people for access. The researcher need to consider ethical issues throughout the research activities and remain sensitive to the impact of his work on those whom he approaches for help, those who provide access and cooperation and those affected by his research. 'In general, the closer the research is to actual individuals in real-world settings, the more likely are ethical questions to be raised' (Wells, 1994: 290). Table 5.17 displays the ethical issues pertaining to this research and approaches taken to address them.

5.6 Summary of Chapter 5

The researcher started this research with a systematic literature review on Six Sigma in chapter 2 and a focused review of team learning in chapter 3. Based on the outcome of the reviews and discussions, the researcher developed a conceptual framework (Figure 3.3) to guide data collection for the research and four research questions. Drawing on findings from the team learning research stream, the researcher took a theory refinement/extension approach by conceptualizing learning behaviours in Six Sigma team as a new refinement and extension of the existing theory. To sum up, this chapter explained the research design choices for this study in order to answer the research questions: an explanatory sequential mixed methods design, a survey research followed by a multiple case study research (*quantitative* → *qualitative*). This chapter also explained that the approaches chosen for this study meet the characteristics of the positivist paradigm. This section justified the choice of the appropriate research methods, while describing some other potential research strategies and methods that could be adopted for dealing with the research questions alternatively. Although the researcher relies on literature to build up his initial argument and conceptual framework which will be tested using survey data in phase one of the research, he aims to enrich the conceptual framework through qualitative data analysis in phase two of the research. The researcher, thus, is open to finding new ideas from qualitative data. As explained, this study uses survey research to to test H1-H8 followed by case research to support the findings. The chapter described the data collection for the survey research and data collection plan for a case study research. The chapter also set out certain quality assessment criteria against which the quality of research will be assessed in chapter 9. The chapter also explained issues in relation to ethics and how the research addresses them. The following chapters will discuss the data analysis of the survey research and data collection and analysis of the case study research. The next chapter will deal with survey data analysis to test *H1, H2, H3, H4,* and *H5.*

Table 5.17 Ethical issues and approaches taken in case research (Source: Miles and Huberman, 1994)

	Ethical issues	**Questions resulting from issues**	**The approach taken in this research**
Issues arising early in the research project	Informed consent	Do the people the researcher is studying have full information about what the study will involve? Is their consent to participate in the interview freely given	Information was sent to each participant in advance of each interview.
	Benefits, costs and reciprocity	What will each party to the study gain from having taken part? What do they have to invest in time and energy or money? Is the balance equitable?	Participants gave their time freely, and all interviews were lasted only as per the agreed schedule and duration.
Issues arising as the project develops	Harm and risk	What might the study do to hurt the people involved? How likely is it that such harm will occur?	The study does not involve any such issues.
	Honesty and Trust	What is my relationship with the people I am studying? Am I telling the truth? Do we trust each other?	None of the interviewees were known to the researcher. Rapport had to be established by email contact and the interview. The purpose of the research was briefed and discussed to build up trust.
	Privacy, confidentiality and anonymity	In what ways will the study intrude, come closer to people than they want? How will information be guarded? How identifiable are the individuals and organizations studied?	All the participating organizations and the individual participants were assured of their anonymity.
Issues arising later in, or after the project	Research integrity and quality	Is the study being conducted carefully, thoughtfully and correctly in terms of some reasonable set of standards?	Interview transcripts were reviewed by the researcher, and sent to the participants for their review and modified according to their feedback.
	Ownership of data and conclusions	Who owns the field notes and analyses: researcher, the organization, research funders? Once the reports are made who controls their diffusion?	All information will be held by the researcher. Any future articles, reports, or academic papers will protect the names of the informants and the organizations.
	Use and misuse of results	Does the researcher have an obligation to help the findings be used appropriately? What if they are used harmfully or wrongly?	The findings will only be used for the purpose of this doctoral thesis and for subsequent academic publications.

CHAPTER 6

SURVEY DATA ANALYSIS: LEARNING BEHAVIOURS AND PERFORMANCE

In this chapter, measurement scales for the two learning behaviours, knowing-what and knowing-how are developed, tested and validated. Hypotheses *H1, H2, H3, H4,* and *H5* are tested using the survey data collected from 324 respondents belonging to 102 project teams (explained in chapter 5) from the two participating organizations.

6.1 Data analysis: resources, psychological safety, learning behaviours, and performance

The analysis controls for project team size, project duration, the leader's project experience and project complexity, as prior research shows that these variables affect project success. The team literature has found that team size affects team dynamics and team performance (Polley & Dyne, 1994). For example, as team size increases, social loafing and responsibility diffusion can affect team learning and project performance. Recent research has also found that the leader's experience affects project success (Easton & Rosenzweig, 2012). Project duration can affect knowledge acquisition and performance. As project duration increases, the team may be affected by temporal variations, for example, in team spirit, and they may place more importance on team relationships than task efficiency (Polley & Dyne, 1994).

Regression analysis was used to test all hypotheses. The mean score for each variable were calculated by averaging the scores of the items belonging to each construct. High correlations among some variables raised concerns of potential multicollinearity issues, so variance inflation factor (VIF) scores were assessed. The highest VIF score within the model was 2.80, well within the threshold value of 10.0 (Kutner et al., 2005).

Note: An earlier version of this chapter was published in *International Journal of Production Economics:* Arumugam, V., Antony, A., and Kumar, M. (2013). Linking learning and knowledge creation to project success: An empirical investigation. Vol 141, issue 1, 388-402.

6.1.1 Scale validity, reliability and aggregation

The construct validity of the measures was assessed by examining dimensionality, criterion-related validity, and discriminant validity. The viability of the team-level constructs was checked by examining within-group agreement (inter-rater agreement) $r_{wg(J)}$ (James, Demaree, & Wolf, 1984) of the multiple response scale items for the analysis.

A principal component analysis (PCA) was conducted with varimax rotation for the 13 items on resources, knowing-what, and knowing-how. Table 6.1 shows the items for the three constructs that captured the extent to which the respondents agree using a 7-point scale from strongly disagree to strongly agree. The internal consistency using Cronbach's alpha for each scale was estimated and found them to be within the acceptable limit (Nunnally and Bernstein, 1994).

Since data on all independent and dependent variables, except psychological safety, were collected from a single respondent (project leader) for this part of the data analysis, Harman's single-factor test was conducted to detect the presence of mono-method bias. In this test, a unrotated factor analysis is performed on all variable scores (both dependent and independent) collected from a single respondent. If a single factor emerges or if one general factor explains most of the covariance in the independent and dependent variables, it is reasonable to conclude that a significant common or mono-method variance is present. Many studies in the operations management literature use this method (Anand et al., 2010). An exploratory factor analysis (EFA) was carried out without specifying the number of factors on the 16 items. The resulting unrotated solution identified three factors with eigenvalues greater than one (variance extracted: 44.32%, 12.7% and 10.26%), suggesting that any mono-method bias that exists is not likely to be problematic (Podsakoff and Organ, 1986).

Table 6.1 Factor analysis

	Resources	Knowing-what	Knowing-how
Availability of belt system	**.60**	.43	-.23
Sponsor supporting projects	**.66**	.11	.41
Database for project documentation	**.75**	.04	.20
Resources for project execution	**.87**	.24	.15
Removal of barriers of project execution	**.84**	.32	.20
Information from outside team	.13	**.84**	.06
Discussion with customers and suppliers	.01	**.57**	.49
Talked to past Six Sigma teams to learn	.33	**.66**	.29
Reflection on process knowledge	.46	**.52**	.43
Carried out observation	.33	.25	**.68**
Conducted group discussions and brainstorming	.39	.24	**.59**
Able to specify the causal variables	.24	.20	**.70**
Changes implemented on process variables	.10	.14	**.76**
Variance explained	3.31	2.04	3.09
%Variance explained	25.63	15.74	23.82
Cronbach α	.85	.75	.81

Principal Component Analysis. Varimax rotation with Kaizer normalization. Rotation converged in 6 iterations

Data aggregation

Responses to goal, method, psychological safety and leader behaviour were obtained from multiple respondents from each team. It is critical to demonstrate high within-team agreement to justify using the team average as an indicator of team-level variables (James, Demaree, and Wolf, 1984). The relative consistency of the scores to scale items of the constructs provided by multiple respondents is referred to interrater reliability (IRR) (Bliese, 2000; James et al., 1984). This agreement is assessed by computing the interrater reliability index $r_{wg(J)}$. This index captures the agreement in terms of the proportional reduction in error variance. Basically, when all the respondents are in perfect agreement, they assign the same score (one of the 1 to 7 in the current survey) to the measure, and hence the observed variance among the respondents will be zero, and in this case the index will become 1. In contrast, when the respondents are in total lack of agreement, the observed variance will asymptotically approach the expected error variance obtained from the theoretical null distribution, and in which case the index approach to 0. Generally, a value of above 0.7 is considered as an acceptable value of the $r_{wg(J)}$ for taking the individual responses to aggregate at the team level response for further analysis (James, Demaree, and Wolf, 1984).

The estimate of this index for multiple respondents is based on the assumption that the targeted items are "essentially parallel" indicators for the same construct (James et al., 1984, p.88).

The formula for $r_{wg(J)}$ is as follows:

$$\frac{J[1-(\overline{S_{x_j}^{\ 2}}/\sigma_{EU}^{\ 2})]}{J[1-(\overline{S_{x_j}^{\ 2}}/\sigma_{EU}^{\ 2})]+(\overline{S_{x_j}^{\ 2}}/\sigma_{EU}^{\ 2})}$$

Where J is the number of items for the measure

$\overline{S_{x_j}^{\ 2}}$ is the mean of the observed variances for the J items,

$\sigma_{EU}^{\ 2} = (A^2 - 1)/12$ is the variance for each item that would be expected if all answers were due exclusively to random measurement error. The subscript "EU" refers to the expected error (E) variance based on the uniform (U) distribution, and A corresponds to the number of alternatives in the response scale.

In this study, A = 7 (since we use a 7-point Likert scale), and thus a $\sigma_{EU}^{\ 2}$ is 4.

$r_{wg(J)}$ values for multi-response variables were computed using the SPSS syntax (Le Breton and Senter, 2008), and the obtained median values are 0.82 for psychological safety and 0.87 for leader behaviour. These values are well above the conventionally acceptable value of 0.70, suggesting high within-team agreement (James et al., 1984). These results provide strong support for aggregation. Team-level variables were then obtained by averaging the within-team member responses on these four measures.

The reliability of all measurement scales were equal to or exceeded the recommended Cronbach's alpha value of 0.7. (Nunnally & Bernstein, 1994). Overall, a series of statistical tests, including multiple tests of reliability, convergent and discriminant validities, and aggregation support the overall measurement quality (Gerbing & Anderson, 1992). Therefore, the measures for this study were considered adequate for further analysis.

Table 6.2 displays descriptive statistics for all variables used in the survey research. The table shows means and standard deviations of all study variables. The entries of standard deviations reveal a wide variation in the study variables. Bivariate correlation among predictor and outcome variables are evident from the table. Control variables do not have any correlation with any of the study variables. Correlation between them also not significant, except, company dummy that has a correlation with team size.

6.1.2 Regression analysis

Table 6.3 displays the results of the regression analyses. All control variables were entered first, followed by other study variables for analysis. In column 1, all study variables, including the control variables are shown. Other columns represent all the models for the regression analysis with the model numbers, and the regression coefficients along with the respective standard error (within brackets) are displayed. R^2 for each model represents the measure of how much of the variability in the column is accounted for by the predictors. For the model M2, its value is.342 and for

Table 6.2 Descriptive statistics of variables

	Alpha	Mean	Std. Dev	1	2	3	4	5	6	7	8	9	10	11
1. Team size	n/a	5.402	1.678											
2. Project duration	n/a	6.887	2.109	.078										
3. Leader experience (log)	n/a	0.225	0.281	.033	.025									
4. Company dummy	n/a	0.509	0.502	.224*	-.183	-.202								
5. Resources	.85	5.368	1.288	.110	-.086	-.031	.407**							
6. Psychological safety	.84	5.571	1.134	-.143	.046	-.112	.091	.552**						
7. Challenging goal	.70	5.671	1.229	.012	-.071	-.071	.170	.445**	.309**					
8. Method	.84	5.595	1.191	.082	.047	.074	.150	.434**	.245**	.333**				
9. Leader behaviour	.95	5.658	1.125	.051	-.011	.034	.164	.595**	.678**	.441*	.398**			
10. Knowing-what	.75	4.897	1.251	.191	-.068	-.013	.210*	.553**	.347**	.398**	.344**	.602**		
11. Knowing-how	.81	5.407	1.006	.049	.066	-.002	.188	.634*'	.558**	.628**	.458**	.773**	.631**	
12. Performance	.91	5.300	1.427	.123	-.039	.005	.240*	.593**	.438**	.656**	.393**	.607**	.564**	.748**

*p< 0.05; ** p< 0.01

Table 6.3 Results of regression analysis of performance on variables

		H1				**H2**			**H3**		
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
	Perf	Perf	K-how	Perf	Perf	Perf	K-what	Perf	Perf	K-how	Perf
Control variables											
Team size	.064(.086)	-.020(.074)	-.109(.049)	.071(.058)	.052(.059)	.054(.072)	.146(.065)	.004(.069)	.145(.078)	.090(.052)	.083(.059)
Project duration	-.002(.068)	.025(.057)	.138(.038)	-.080(.046)	-.066(.046)	.006(.057)	-.042(.051)	.020(.053)	-.041(.061)	.058(.040)	-.081(.046)
Leader experience (log)	.103(.508)	.093(.430)	.028(.350)	.074(.342)	.075(.340)	.072(.425)	-.011(.382)	.076(.400)	.141(.454)	.086(.302)	.081(.345)
Company dummy	.246*(.298)	.154(.256)	.109(.168)	.086(.205)	.082(.204)	.004(.270)	-.060(.243)	.024(.255)	.186*(.268)	.144(.178)	.086(.205)
Independent variables											
Resources						.588***(.099)	.557***(.089)	.399***(.110)			
Psychological safety									.459***(.112)	.564***(.075)	.066(.103)
Knowing-what		.538***(.098)	.638***(.064)		.116(.100)			.340**(.107)			
Knowing-how				.734***(.096)	.661***(.123)						.696***(.116)
R^2	.073	.342	.427	.585	.593	.360	.326	.438	.273	.350	.588
Adj R^2	.034	.308	.397	.564	.567	.327	.291	.403	.235	.316	.562
F	1.898	9.997***	14.301***	27.094***	23.053***	10.806***	9.305***	12.340***	7.210***	10.329***	22.609***

*$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

M: Model. H: Hypothesis

All values are standardized betas. Standard errors are given within parentheses.

the model M5, the value is.593. In other words, the variance accounted for being 34.2% and 59.3% respectively. For the model M5, the value increases by 0.251 (=.593-.342), and thus 25.1% increase. This points out that knowing-how, which is the new addition in the model variables, accounts for an extra 25.1% of the variance in performance scores. The adjusted R^2 gives us some ideas of how well the model generalizes and ideally we would like its value to be the same, or very close to, the value of R^2. For the model M5, the difference is.593-.567, which is 0.026 or 2.6%. This shrinkage means that if the model were derived from the population rather than a sample it would account for approximately 2.6% less variance in the outcome.

The mediating role of knowing-how on the relationship between knowing-what and performance (H1) was tested using Baron and Kenny's (1986) three-step method: (1) the proposed mediator predicts the dependent variable, (2) the independent variable predicts the mediator, and (3) the contribution of the independent variable drops substantially for partial mediation and becomes insignificant for full mediation. In this analysis, knowing-what was associated positively with project success (β=0.538, $p < 0.001$), knowing-what predicted knowing-how (mediator) (β=0.638, $p < 0.001$), knowing-how influenced project success (β=0.734, $p < 0.001$) and the contribution of knowing-what on performance became non-significant (β= 0. 116, non-significant) when entered into the regression model with knowing-how, which remained significant (β=0.661, $p < 0.001$). These results satisfy the conditions for the complete mediation of knowing-what by knowing-how on its effect on performance. Therefore, H1 was supported, but no significant direct effect of knowing-what on performance was found, and hence knowing-how completely mediates the effects of knowing-what on its impact on performance.

Tests for the significance of mediated effects (Frazier, Baron, & Tix, 2004; MacKinnon et al., 2002; Preacher and Hayes, 2004) are recommended for the confirmation of mediation effects. The first test is *Sobel* test, which provides a more direct test of the indirect effect. This test is conducted by comparing the strength of the indirect effect of X (independent variable) on the Y (dependent variable) to the point null hypothesis that it equals zero (see Figure 6.1).

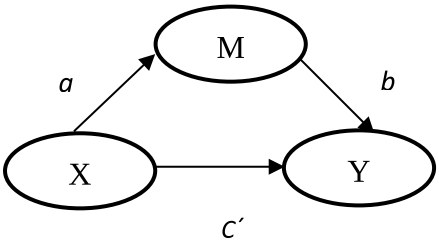


Figure 6.1 Mediation effect

The indirect effect of X on Y is defined as the product of the coefficient for X→M path (a) and the M→Y path (b), or $a*b$. In most situations, $a*b= c\text{-}c´$ where c is the simple (i.e., total) effect of X on Y, not controlling for M, and $c´$ is the X→Y path coefficient after the addition of M to the regression model. If the standard errors of a and b are represented by s_a and s_b respectively, then the standard error of the indirect effect is given by:

$$s_{ab} = \sqrt{}(b^2 s_a^2 + a^2 s_b^2 + s_a^2\, s_b^2)$$

The test involves the following steps:

(1) $a*b$ is divided by s_{ab} to get a critical ratio

(2) The critical ratio is compared with the critical value from the standard normal distribution appropriate for a given alpha level. Assuming that the sampling distribution of $a*b$ is normal, for an alpha value of .05, the critical value is +/- 1.96.

Second, scholars recommend (Preacher and Hayes, 2004) the use of nonparametric bootstrapping procedures for testing the indirect effect, as the standard procedures (Baron and Kelly's method) may provide an erroneous conclusion on the mediation result, due to the following:

- It is possible to observe a change from a significant X→Y path to a nonsignificant X→Y path upon the addition of a mediator to the model with a very small change in the absolute size of the coefficient.
- It is possible to observe a large change in the X→Y path upon the addition of a mediator without observing an appreciable drop in statistical significance.

- Finally, it is also possible for the occurrence of (1), if either *a* or *b* appears to be statistically different from zero when one of them is, in fact, zero in the population.

The procedure involves bootstrapping the sampling distribution of *a*b* and derive a confidence interval with the empirically derived bootstrapped sampling distribution. This makes no assumptions about the shape of the distributions of the variables or the sampling distribution of the statistics (Efron and Tishhirani, 1993). This procedure can be applied even if the sample size is small. The macro available in SPSS software carries out the bootstrapping by taking a large number of samples (usually 1000 or 5000) of size *n* (*n* is the original sample size) from the data, sampling with replacement, and computing the indirect effect, *a*b* in each sample. The estimated *a*b* values are sorted from low to high. For a 95% confidence interval, the lower limit of the confidence interval is defined as the 25th score in the sorted list, and the upper limit is defined as the 976th score in the distribution. If zero is not included in the confidence interval, we can conclude that the indirect effect is significantly different from zero at $p<0.05$. Both the Sobel test and bootstrapping procedures can be carried out by the macro available in SPSS (PROCESS procedure, an add-on to SPSS by Andrew. F. Hayes: http://www.afhayes.com/).

For testing the Hypothesis 1, the above two tests were conducted using the macros in SPSS software. The Sobel test provides evidence of a significant mediating effect with a test statistic of 5.566 ($p<.\ 001$). Furthermore, using the bootstrapping procedure for the indirect effect shows a confidence interval of [0.315, 0.649] ($p< .001$). Hence, Hypothesis 1 is supported as predicted.

Going by the reported adjusted R^2 values for M4 and M5 (0.564 and 0.567), it appears that knowing-how, by itself (in M4), is a powerful predictor for performance than both knowing-what and knowing-how, together, as the difference between them is very small (0.003). It is, however, to be noted that the result should not be interpreted as knowing-what being redundant. Rather, this result should be seen in the light of the conceptualization of the variables, with knowing-what being the necessary antecedent to knowing-how.

The second panel (H2) and M2 in Table 6.3 test hypothesis 2. Resources were associated positively with project success (β=0.588, $p < 0.01$), resources predicted knowing-what (mediator) (β=0.557, $p < 0.01$), knowing-what influenced project success (M2: β=0.538, $p < 0.05$), and the contribution of resources became less (β=0.399, $p < 0.05$) when entered into the regression model with knowing-what, which remained significant (β=0.340, $p < 0.01$). These results, in view of the third step of Baron and Kenny's procedure (1986), the results do not satisfy the conditions for the mediation effect of knowing-what on the relationship between resources and performance. However, the last step in the analysis has a positive increase of 0.076 in R^2 value (from 0.327 for M6 to 0.403 for M8), meaning an increase of 7.6% variance being explained by the introduction of knowing-what. In view of our conceptualization of knowing-what affecting the project outcome through knowing-how, we carried out additional regression analysis to test the combined mediation effect of knowing-what and knowing-how on the effect of resources on performance. In the regression analysis, we used all predictors (resources, knowing-what and knowing-how) without any control variables (to gain more degrees of freedom). Results are shown in Table 6. 4.

Table 6.4 Results of regression analysis without control variables (H2)

	M12	M13	M14	M15
	K-what	Per	Per	Per
Resources	.553***(.081)	.593***(.089)	.405***(.101)	.171*(.096)
Knowing-what			.340***(.104)	.110(.098)
Knowing-how				.570***(.132)
R^2	.306	.352	.432	.590
Adj R^2	.299	.345	.421	.577
F	44.037***	54.245***	37.653***	46.958***

*p< 0.05; ** p< 0.01; *** p< 0.001

M: Model. H: Hypothesis

All values are standardized betas.

Per: Performance; Standard errors are given within parentheses.

In the model M15, knowing-what was found to be non-significant (β value being 0.110) with resources and knowing-how predicting performance (β=0.171, $p < 0.05$; β=0.570, $p < 0.001$); This model was found to be highly significant, (F=46.958, $p <$

0.001), with R^2 value changed from 0.421 (resources and knowing-what as predictors in M14) to 0.577 (resources, knowing-what and knowing-how as predictors). The results of the M12, M13 and M14 (Baron and Kenny, 1986) together with the results of M15 provide support for the mediation effect of both knowing-what and knowing-how. Furthermore, we evaluated the significance of the total indirect effect of resources on performance by using the approach proposed by Preacher and Hayes (2004, 2008) and Hayes (2009), using a bootstrap sampling. Brief details and findings are given in Appendix II. We found that the mediation effect of knowing-what and knowing-how on the relationship between resources and performance is highly significant ($p < 0.005$). Therefore, hypothesis H2, which posits that resources influence performance through knowing-what and knowing-how, was supported.

The results of H3 are reported in panel 3 (H3) showing knowing-how mediated the effect of psychological safety on project performance. Psychological safety was associated positively with project success ($\beta=0.459$, $p<0.001$), psychological safety predicted knowing-how (mediator) ($\beta=0.564$, $p< 0.001$), knowing-how influenced project success (column M4: $\beta=0.734$, $p< 0.001$), and the contribution of psychological safety on performance became non-significant ($\beta=-0.066$, non-significant) when entered into the regression model with knowing-how, which remained significant ($\beta=0.696$, $p<0.001$). These results satisfy the conditions for complete mediation of psychological safety by knowing-how on its effect on performance.

Tests for the significance of mediated effects (Frazier, Baron, & Tix, 2004; MacKinnon et al., 2002) were also conducted for the confirmation of mediation effects. A follow-up using the Sobel test (Baron & Kenny, 1986) provides evidence of a significant mediating effect with a test statistic of 5.384 ($p<.001$). Furthermore, using a bootstrapping procedure for the indirect effect shows a confidence interval of [0.311, 0.809] ($p<.001$). Hence, Hypothesis 3 is supported as predicted.

The control variables (team size, project duration and leader experience) had no influence on performance. This study demonstrates that Six Sigma resources are related positively to knowing-what, and psychological safety is related to knowing-how, which, in turn, mediates the effect of knowing-what on project performance.

6.2 Data analysis: method, leader behaviour, and learning behaviours

Knowing-what

Table 6.5 displays the results of the regression analysis. All control variables were entered first, followed by other study variables for analysis. The mediating role of leader behaviour on the relationship between method and knowing-what (H4) was tested using Baron and Kenny's (1986) three-step method as done earlier. In this analysis, leader behaviour was associated positively with knowing-what (β=0.583, $p < 0.001$) in M18, method predicted leader behaviour (mediator) (β=0.380, $p < 0.001$) in M16, method influenced knowing-what (β=0.319, $p < 0.001$) in M19, and the contribution of method on knowing-what became non-significant (β=-0. 114, non-significant) when entered into the regression model (M20) with leader behaviour, which remained significant (β=0.540, $p < 0.001$). These results satisfy the conditions for the complete mediation of the effect of Method on knowing-what by leader behaviour. Tests for the significance of mediated effects (Frazier, Baron, & Tix, 2004; MacKinnon et al., 2002) were also conducted for the confirmation of mediation effects. A follow-up using the Sobel test (Baron & Kenny, 1986) provides evidence of a significant mediating effect with a test statistic of 3.554 (p<.001). Furthermore, using a bootstrapping procedure for the indirect effect shows a confidence interval of [0.106, 0.423] (p< .001). Therefore, H4 was supported.

Knowing-how

Referring to Table 6.7 again, with a similar argument given above, it can be shown that leader behaviour partially mediates the effect of the method on knowing-how. The results indicate that leader behaviour was associated positively with knowing-how (β=0.762, $p < 0.001$) in M22, method predicted leader behaviour (mediator) (β=0.380, $p < 0.001$) in M16, method influenced knowing-how (β=0.437, $p < 0.001$) in M23,

and the contribution of method on knowing-how became less significant (β=-0. 172, $p < 0.05$) when entered into the regression model (M24) with leader behaviour, which remained significant (β=0.698, $p < 0.001$). These results satisfy the conditions for the partial mediation of the Method by leader behaviour in its effect on knowing-how.

Table 6.5 Regression analysis: method, leader behaviour, and learning behaviours

	M16	M17	M18	M19	M20	M21	M22	M23	M24
	Leader	K-what	K-what	K-what	K-what	K-how	K-how	K-how	K-how
Control variables									
Team size	-.055(.065)	.156 (.076)	.152(.061)	.145(.072)	.148(.061)	-.009(.062)	-.015(.040)	-.024(.056)	-.020(.039)
Project duration	-.009(.051)	-.050(.060)	-.061(.048)	-.073(.057)	-.068(.048)	.106(.048)	.091(.031)	.073(.044)	.080(.030)
Leader experience (log)	.029(.383)	.018(.446)	-.023(.362)	-.016(.427)	-.032(.362)	.039(.363)	-.014(.234)	-.008(.330)	-.028(.229)
Company dummy	.112(.227)	.170(.262)	.065(.215)	.113(.253)	.052(.215)	.217*(.213)	.080(.139)	.140(.195)	.061(.136)
Independent variables									
Method	.380***(.090)			.319***(.100)	.114(.091)			.437***(.077)	.172*(.058)
Leader behaviour			.583***(.090)		.540***(.096)		.762***(.058)		.698***(.061)
R²	.170	.069	.398	.167	.409	.047	.610	.230	.634
Adj R²	.127	.030	.367	.123	.371	.008	.590	.190	.611
F	3.936**	1.787	12.694***	3.836**	10.947***	1.205	30.015***	5.738***	27.442***

p*< 0.05; ** *p*< 0.01; * *p*< 0.001

M: Model.   H: Hypothesis

All values are standardized betas. Standard errors are given within parentheses.

Tests for the significance of mediated effects (Frazier, Baron, & Tix, 2004; MacKinnon et al., 2002) were also conducted for the confirmation of mediation effects. A follow-up using the Sobel test (Baron & Kenny, 1986) provides evidence of a significant mediating effect with a test statistic of 3.988 (p<.001). Furthermore, using a bootstrapping procedure for the indirect effect shows a confidence interval of [0.105, 0.386] (p< .001). Hence, Hypothesis 5 is supported as predicted.

6.3 Summary of chapter 6

Based on the existing literature, this chapter conceptualized two learning behaviours found to be in practice in Six Sigma projects: knowing-what and knowing-how. This answers the research question RQ1. Measurement scales for these constructs were developed and validated using the data collected from 324 respondents (102 projects). The effects of the two learning behaviours on project performance were investigated using the survey data and the results showed that knowing-what behaviour impacts project performance through knowing-how behaviour, confirming H1 that knowing-what is antecedent to knowing how. This finding answers the RQ2.

From the conceptual framework developed in chapter 3, the researcher selected four critical managerial factors with potential influencing effect on learning and examined their impacts on the two learning behaviours and project performance. The researcher developed four hypotheses linking these factors and learning behaviours and investigated using the survey data. The results showed that resources (technical factor) impact project performance through knowing-what and knowing-how (H2); team psychological safety (social factor) impacts knowing-how, which in turn impacts project performance (H3); Method impacts both the learning behaviours through project leader (H4 and H5). Overall, this research establishes that the four factors considered for investigation (resources, psychological factors, project leader and structured method) all impact learning behaviours and in turn project performance, and thus answers RQ3. The next chapter through quantitative data analysis tests H6, H7, and H8 to answer RQ4.

CHAPTER 7

SURVEY DATA ANALYSIS: GOAL THEORY AND SOCIOTECHNICAL SYSTEM THEORY PERSPECTIVE

This chapter conducts data analysis and tests hypotheses H6, H7 and H8 and answers the research question 4:

RQ4: *How do social aspects of the project team (goal) and technical aspects of project execution (method) interact to impact project performance through knowledge creation?*

7.1 Data

Data for this study is from 324 responses (102 project teams). Responses are from project leaders and members as shown in Table 7.1. Responses to the goal and method were obtained from both the leaders and members and to knowledge and performance from the project leaders.

Table 7.1 Survey responses

Factors	**Leader**	**Member**
Challenging goals	√	√
Method	√	√
Knowledge	√	
Performance	√	

7.1.1 Scale validity, reliability, and aggregation

The construct validity of the measures was assessed by examining dimensionality, criterion-related validity, and discriminant validity. The researcher also checked the viability of the team-level constructs by examining within-group agreement (inter-rater agreement) $r_{wg(J)}$ (James, Demaree, & Wolf, 1984) of the multiple response scale items for the analysis.

Note: An earlier version of this chapter was presented at the Decision Science Institute Annual meeting held at San Francisco, USA in November 2012. It received an outstanding achievement award in the category of theory/empirical research stream.

A four-factor measurement model consisting of goal, knowledge, method and performance, comprising 12 items was estimated using AMOS 22 (add on to SPSS Statistical analysis software) and it was found that the measurement model fit the data well: χ^2 (48) = 68.975, with a probability of 0.025, root mean square error of approximation (RMSEA) = 0.06, goodness-of-fit index (GFI) = 0.90, TLI =0.97, confirmatory fit index (CFI) = 0.98, with all values within the acceptable limits (Hu & Bentler, 1999). This analysis also showed that all items loaded significantly on their associated constructs ($p < 0.001$), thus confirming the constructs' convergent validity (Bagozzi & Yi, 1991). In addition, the hypothesized four-factor model was compared with a likely rival model to establish divergent validity. For example, because both the knowledge and the performance items are related to the outcome of the project, it is possible to combine these items into a single factor. This alternative three-factor model yielded a very low fit, $\chi^2(51)$ =170.41, p<.001 RMSEA= 0.15, GFI = 0.79, TLI =0.83, CFI =0.87, indicating that the hypothesis model had a better fit than this alternative model combining the knowledge items with the performance items.

Construct validity is assessed by calculating average variance extracted (AVE) which is the mean-variance extracted for items loaded onto a construct and indicates convergence (Hair, et al., 2010). AVE is the total of the squared standardized factor loadings (or standardized regression weights in AMOS) divided by the number of items. Established heuristics (Fornell & Larcker, 1981; Hair, et al., 2010) recommend that this should be ideally no less than .5 indicating adequate convergence and that there is not more error in the items than there is explained by the construct measures. The magnitudes of the average variance extracted (AVE) of all constructs (.53 to .78) are found to be greater than the accepted value of 0.50, thus providing further evidence of the convergent validity of the scales.

Discriminant validity is assessed by comparing the shared variance (squared correlation) between each pair of constructs against the average of the AVE for these two constructs. Within each of the six possible pairs of constructs, the shared variance estimated was found to be lower than the average of their AVEs, confirming discriminant validity (Fornell & Larker, 1981; Hair, et al., 2010). The reliability of all measurement scales was equal to or exceeded the recommended Cronbach's alpha value of 0.7 (Nunnally & Bernstein, 1994).

$r_{wg(J)}$ values for multi-response variables (goal and method) were computed and obtained median values of .75 for goal and .89 for method. These values are well above the conventionally acceptable value of .70, suggesting high within-team agreement. Team-level variables were created by averaging the within-team member responses on the goal and method measures.

Overall, a series of statistical tests, including multiple tests of reliability, convergent and discriminant validities, and aggregation support the overall measurement quality (Gerbing & Anderson, 1988). Therefore, the measures were considered adequate for further analysis.

7.2 Analysis and results

The mean score for each study variable was calculated by averaging the scores for each construct. As the data on the project experience of the leaders were found to be highly skewed, they were log-transformed to the analysis, and the transformed data were found to be normal. Table 7.2 provides the descriptive statistics and correlations for the variables.

Regression analysis was used to test the three hypotheses involving mediation and moderation. Scholars have suggested a number of ways of testing the mediated moderation model. Of these, path analytic methods have been shown to have the greatest statistical performance (Edwards & Lambert, 2007; MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). Incorporating both regression and path analyses overcomes all the shortcomings of current approaches that are used for testing mediated moderation effects. Furthermore, powerful bootstrapping methods are incorporated to generate confidence intervals rather than point estimates for the indirect effects. This helps avoid any potential power problems caused by asymmetric and other non-normal sampling distributions of conditional and indirect effects (MacKinnon et al., 2002).

Table 7.2

Descriptive Statistics of variables

		Mean	Std Dev	1	2	3	4	5	6	7
1	Team size	5.402	1.678							
2	Project duration	6.888	2.109	.078						
3	Leader's experience (log)	0.225	0.281	.033	.025					
4	Company dummy	0.509	0.502	.224*	-.183	-.202*				
5	Goal	5.671	1.229	.012	-.071	-.071	.170			
6	Knowledge created	5.523	1.214	.082	-.008	-.020	.181	.530**		
7	Method	5.595	1.191	.082	.047	.074	.150	.338**	.296**	
8	Performance	5.404	1.359	.095	-.036	.037	.242*	.676**	.732**	.394**

*p<0.05. **p<0.01

Table 7.3 presents the results of the hierarchical regression analysis. The control variables were entered first, followed by the other study variables. As Aiken and West (1991) suggest, all independent variables were mean-centred to reduce multicollinearity. Hypothesis 1, which predicted that knowledge mediates the effect of goals on project performance, was tested using Baron and Kenny’s (1986) three-step method: (1) the proposed mediator predicts the dependent variable, (2) the independent variable predicts the mediator, and (3) the contribution of the independent variable drops substantially for partial mediation and becomes insignificant for full mediation when both independent and mediator variables are entered into the regression model. In the results of this analysis, goal is associated positively with project performance (β =.660, $p < .001$) in M6, goal predicts knowledge (mediator) (β =.519, $p < .001$) in M2, knowledge influences project performance (β =.710, $p < .001$) in M5 and the contribution of goal to performance lessens (β = 400, $p < .001$) when entered into the regression model with knowledge, which remains significant (β = .502, $p < .001$) in M7. These results satisfy the need for the partial mediation of goal through knowledge on its effects on performance. Tests for the significance of mediated effects (Frazier, Baron, & Tix, 2004; MacKinnon et al., 2002) were also conducted for the confirmation of mediation effects. A follow-up using the Sobel test (Baron & Kenny, 1986) provides evidence of a significant mediation effect with a test statistic of 4.97 ($p<.001$). Furthermore, using a bootstrapping procedure for the indirect effect shows a confidence interval of [.161, .476] ($p< .001$). Hence, Hypothesis 6 is supported as predicted.

Table 7.3 Summary of the Regression Analyses Results

	Knowledge created			Performance					
	M1	M2	M3	M4	M5	M6	M7	M8	M9
Control variables									
Team size	.040 (.075)	.050(.064)	.046(.065)	.035(.082)	.007(.057)	.048(.061)	.023(.050)	.020(.049)	.031(.048)
Project duration	.021(.059)	.041(.051)	.027(..053)	.005(.065)	-.010(.045)	.031(.413)	.010(.039)	.002(.039)	-.018(.039)
Leader's experience (log)	.015(.441)	.034(.38)	.020(.383)	.086(.485)	.076(.337)	.111(.361)	.094(.293)	.082(.293)	.100(.283)
Company Dummy	.179^(.259)	.096(.225)	.079(.230)	.253*(.285)	.126^(.201)	.148^(.214)	.099(.175)	.088(.175)	.095(.170)
Independent variables/ indirect effects									
Goal		.519***(.086)	.479***(.092)			.660***(.082)	.400***(.078)	.374***(.079)	.373***(.076)
Knowledge created					.710***(.078)		.502***(.079)	.488***(.079)	.493***(.076)
Moderation									
Method			.113(.095)					.103(.073)	.097(.070)
Method * Goal			-.015(.056)						-.231**(.059)
Method * Knowledge									.260**(.067)
R²	.035	.296	.307	.068	.554	.490	.667	.676	.708
Adj R²	-.005	.259	.256	.029	.531	.463	.646	.652	.680
F	.833	8.059***	5.952***	1.758	23.848***	18.423***	31.722***	28.005***	24.816***

N= 102 project teams (222 members and 102 leaders). M = Model

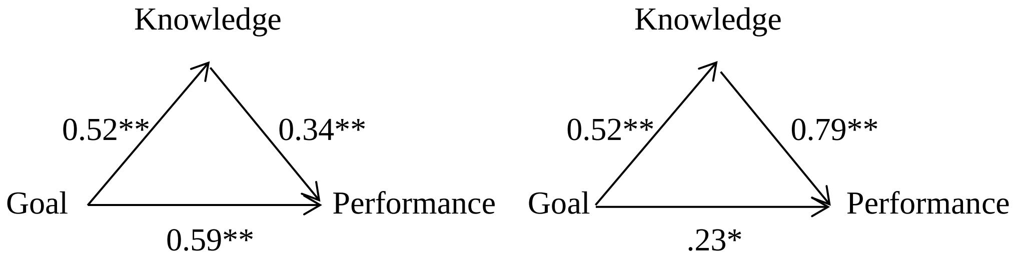
^*p*<.1. **p*<.05. ***p*<.01. ****p*<.001

All coefficients are standardized. Standard errors are given within parentheses.

Hypothesis 7 predicted that the method negatively interacts with goal in its effect on performance (direct path). Hypothesis 8 predicted that the method interacts positively with knowledge in influencing its relationship with performance in the second stage indirect path. To test these moderation effects of method on the effect of goal on performance through knowledge, interaction terms were entered into the regression for performance. The resulting model, M9, is highly significant (F = 24.816, *p*< .001) and the coefficient for the interaction term of method and goal is significant and negative (β =- .231, *p*< .01) and so also for method and knowledge (β = .260, *p*< .01). These two variables account for a significant 3.4% of the variance in performance beyond that variance accounted for by the control variables and the independent variables (goal and knowledge), as reported by M7. Thus, Hypotheses 7 and 8 are fully supported by the data. The result, as shown in M3, reveals no effect of the method on knowledge. This result is also consistent with the findings of Choo et al. (2007b), who found that method does not have any direct effect on knowledge, but acts only indirectly to exert an impact on knowledge.

As noted earlier, the researcher followed Edwards and Lambert (2007) in testing for the mediated moderation effects suggested by the hypothesized model. He ran the SPSS "constrained non-linear regression" syntax module suggested by Edwards and Lambert (2007), which was based on the bootstrapping function, to assess direct, indirect and total effects of goals on performance at low (one standard deviation below the mean) and high (one standard deviation above the mean) levels of the moderator variable (method). Bias-corrected confidence intervals at two selected levels of method, with 1,000 random samples and with replacement from the full sample (Stine, 1989) were estimated. The results are reported in Table 7.4 and depicted in Figure 7.1.

Referring to Table 7.4, significant path coefficients for the second stage at both low and high levels of method (β =0.34, *p*< .01 and β =0.79, *p*< .01 respectively) signify the mediating effects of knowledge on the relationship between goal and performance, which is consistent with the earlier finding that supports Hypothesis 6. The differences in the second stage (β=.45, *p*< .05), indirect effect (β=.23, *p*< .05) and direct effect (β=-.36, *p*< .05) are all shown to be significant, supporting oderation at the second stage and for the direct effect, thus confirming Hypotheses 7 and 8.



A. Simple effects for low Method B. Simple effects for high Method

* *p* < .05 ** *p* < .01

Panels A and B show that the method moderates the paths from knowledge to performance and more so for higher method than for low method. The path from the goal to performance is also moderated by method, more strongly when the method is low. The indirect effect is stronger for high method (0.41**, *p* < .01) than for low method (0.18**, *p* < .01).

Figure 7.1: Mediated models showing the simple effects of low and high method/tools

Table 7.4

Results of the moderated path analysis: Direct, indirect and total effects of goal on project performance at low and high levels of method

Path	First Stage	Second Stage	Indirect effects	Direct effects	Total effects
Simple path for low method	.52**	.34**	.18**	.59**	.76**
Simple path for high method	.52**	.79**	.41**	.23*	.64**
Difference	0	.45*	.23*	-.36*	-.12
Mean	.52**	.57**	.29**	.41**	.70**

N = 102; Low method refers to one standard deviation below the mean of the method and high method to one standard deviation above the mean of the method. First Stage = Path from goal to knowledge; Second Stage = Path from knowledge to performance; Direct effects = Path from goal to performance.

* *p* <.05; ** *p*<.01.

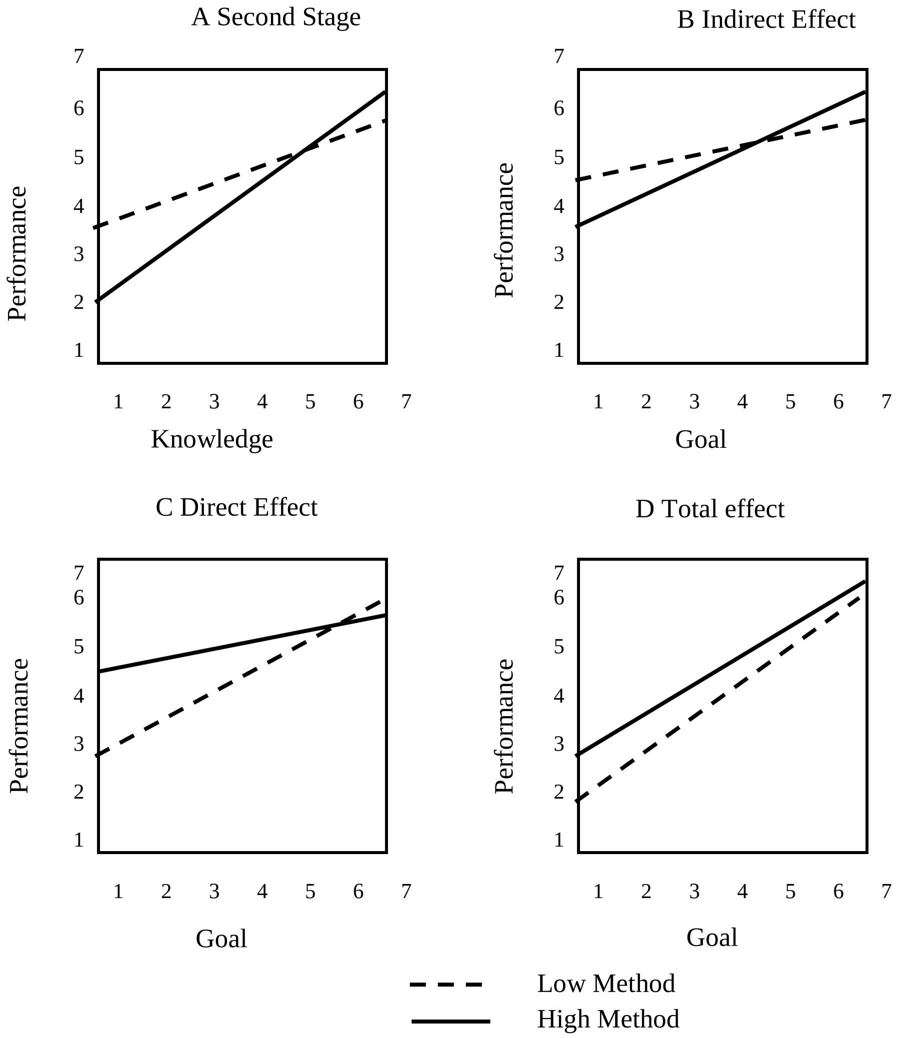


Figure 7.2 Plots of simple paths and effects with method as the moderator

The results also reveal that the indirect effect (β=.41, *p*< .01) is stronger when method is high, whereas the direct effect is stronger (β=.59, *p*< .01) when the method is low, supporting the differential moderation effects of method on direct and indirect paths as hypothesized and established earlier by the regression analysis. Overall, these results are consistent with all the three hypotheses, showing the mediation of knowledge on the relationship between goal and project performance, as well as the existence of moderation by the method on the linkage between goal and performance via knowledge.

The intercepts for both low and high levels of the moderator were then estimated for the second stage indirect effects, direct effects and total effects using the procedure given by Edwards and Lambert (2007). Using the slopes from Table

7.4 and the estimated intercepts, Figure 7.2 shows the simple slope curves for the second stage indirect effects, direct effects, and total effects. For display purposes, the axes of these figures have been converted back to their original scales (1 to 7 in this study) to facilitate interpretation, as the plot does not alter the form of the plotted interaction (Aiken & West, 1991).

In Figure 7.2, Panel A shows that for the second stage (knowledge–performance) of the indirect effect, the relationship between knowledge and performance is steeper for the projects with a high level of adherence to the method. This finding highlights that for the teams studied, closer adherence to the method enhanced the application of knowledge gained by teams in improving the process and implementing the changes identified at a faster rate than when adherence to the method was low. When the level of acquired knowledge was high, high, the performance level was greater for project teams with close adherence to the method than for those that were less faithful in following it. It also shows that when the knowledge created is low to medium, a low level of method is sufficient to attain higher performance. In contrast, when the knowledge gained is high, it is likely that only a high level of method can help convert the newly created knowledge into implementable solutions and subsequent implementation to achieve higher performance. This observation underscores the importance of adherence to the method for projects aimed at process improvement in which teams need to create knowledge to solve problems.

Panel B in Figure 7.2 shows the indirect effects (knowledge route), which shows similar patterns as seen in Panel A. The high method path is found to be stronger as expected. Our findings further point out that low goal (do your best) projects do not need excessive adherence to the method to attain better performance; in fact it may lower the performance as pointed out by Linderman et al. (2006). This provides an important lesson for Six Sigma practitioners and project team members.

It is interesting to observe the nature of the slopes in Panels B and C, for the indirect effect and direct effect paths respectively. High method has a steeper slope in Panel B (indirect effect) and in contrast, low method has a steeper slope in Panel C (direct effect), indicating that the effect of goal on performance is weaker for the direct path when method is high as expected in Hypothesis 2. The lines in Panel C further reveal that low method results in higher performance when a very high goal is set. The total effect is reflected in Panel D, which indicates that for high method, performance is greater across all levels of goal, suggesting that the moderator method has positive overall effects on the influence of goal on performance via knowledge as predicted.

7.3 Summary of chapter 7

This chapter answered the ***Research Question 4:*** *How do social aspects of the project team (goal) and technical aspects of project execution (method) interact to impact project performance through knowledge creation?*

The findings showed that the challenging goal and structured method have an interesting interaction effect with knowledge created in project teams to impact performance. A path coefficient analytical framework incorporating both regression and path analysis was used to test the mediated moderation model (goal-knowledge-performance with method as moderator) using the survey data. The results show that a team employing a less structured method can enhance its performance relative to a team with a highly structured method when a challenging goal is set in the context of process improvement projects in which team create knowledge to solve problems. These findings enrich our understanding of the relationship between challenging goals, the Six Sigma method, knowledge and performance in Six Sigma projects and have significant implications for research and practice. The next chapter discusses the case study data analysis and how the findings support the survey research findings.

CHAPTER 8

MULTIPLE CASE STUDY ANALYSIS

Consistent with the plan of collecting qualitative data to corroborate and explain the findings of the survey research, the researcher conducted semi-structured interviews and collected data from five Six Sigma project teams. The following steps were followed while conducting this multiple case study, as suggested by Eisenhardt (1989), Voss et al. (2002) and Yin (2009).

1. Developing the research framework, constructs and research questions (Chapter 2, 3)
2. Choosing case study type (Chapter 5)
3. Selecting cases (Chapter 5)
4. Developing research instruments and protocols (Chapter 5)
5. *Entering the field and collection of data*
6. *Analyzing data*
7. *Reaching closure*

$\}$ To be addressed in this chapter

The research questions and the conceptual framework were developed after an in-depth literature review and gap analysis in Chapter 2 and 3. Choosing the case study type, selecting cases and developing research instruments and protocols were explained in Chapter 5. This chapter will deal with data collection, data analysis and reaching closure of the case study research with the primary objective of finding the learning practices and their potential antecedents and performance consequences and to see if the results support the earlier findings of the survey research.

While selecting the case projects, the researcher adopted systematic procedures in order to elaborate on the unexpected quantitative results found in chapter 6 and 7. Follow-up quantitative analysis using the survey data to cross-check the emergent themes, if any, from the case data analysis was also carried out (explained later in this chapter), thus observing interaction between qualitative and quantitative study strands. In summary, this chapter discusses the data collection and analysis of the multiple case study research as part of the sequential ''*Quantitative* → *Qualitative*'' research design.

8.1 Data collection

The steps the researcher followed for data collection are shown in Figure 8.1. As suggested by Eisenhardt (1989) and Yin (2009), the research typically combined data collection methods such as archives, interviews, questionnaires, and observations. These helped to triangulate data and with this data triangulation, the potential problem of *construct validity* was addressed. The data collected in the case studies are interview-transcripts (audio recording and write-ups), researcher's field notes, notes on various displays about Six Sigma in the organizations (notice board, in-house publications, etc.), and other information about the company from external sources (media and internet). Interview data were recorded electronically and also documented as a standard write-up. A research diary was kept with all day to day events and tasks and other observations.

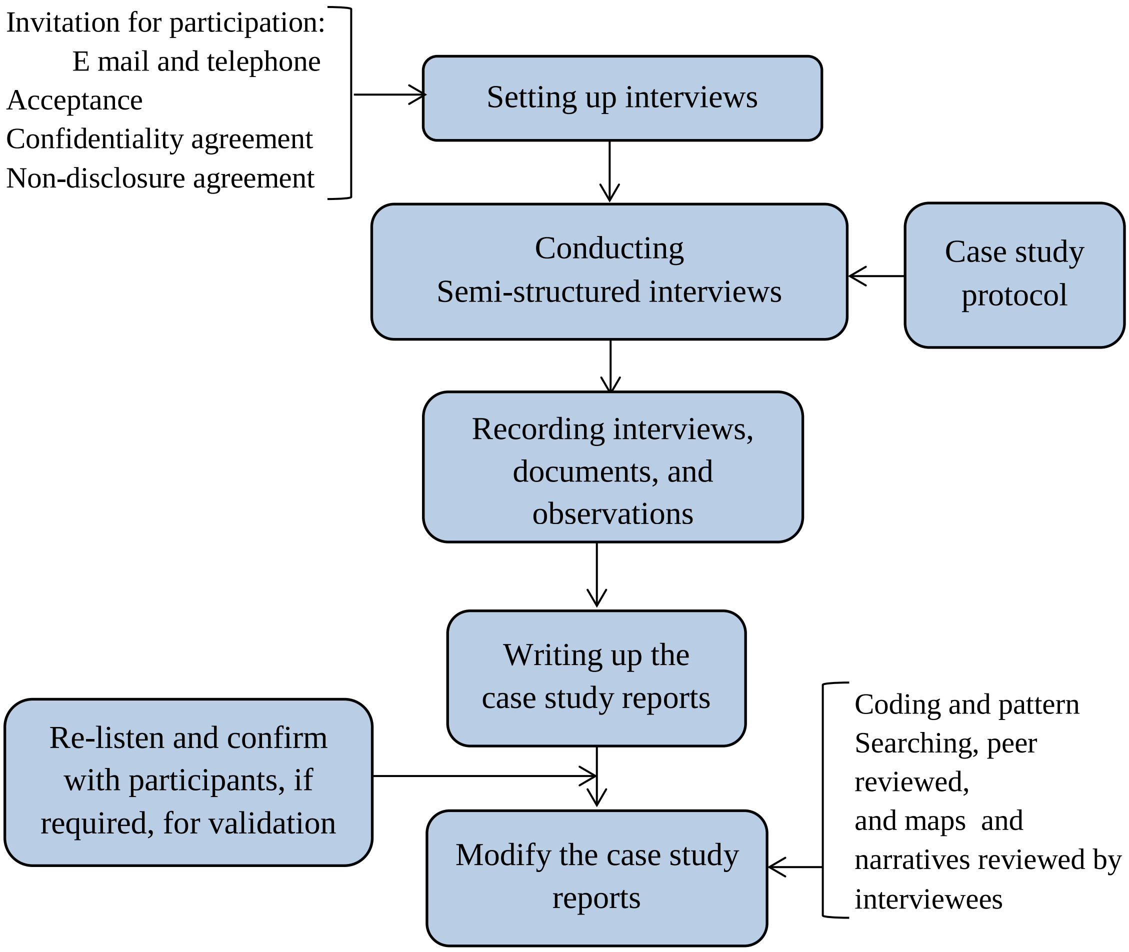


Figure 8.1 Steps to follow in case studies (Yin, 2009 and Eisenhardt, 1989)

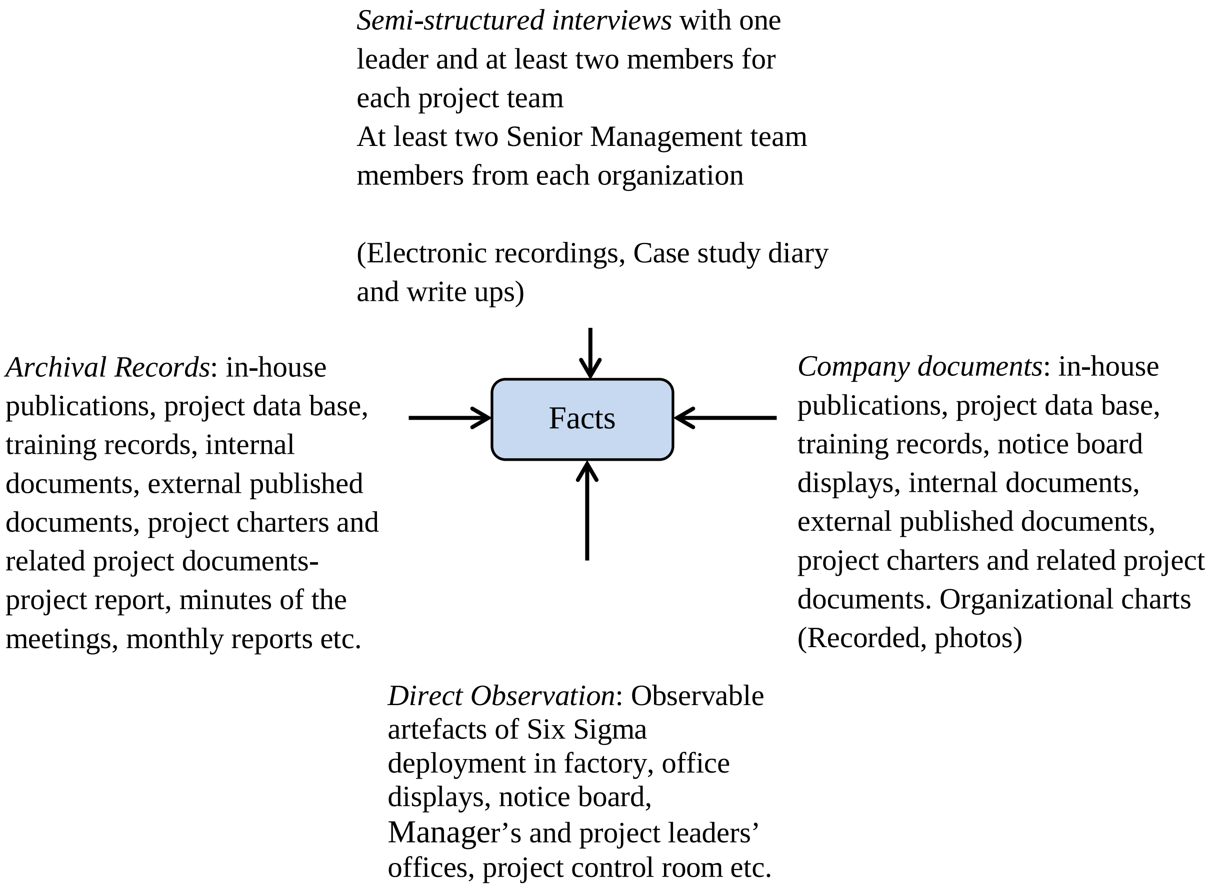
Interviews: Interviews are guided conversations rather than structured queries (Yin, 2009). ‘‘Interviews are an essential source of case study evidence because most case studies are about human affairs or behavioural events’’. Interviews hence can provide good information about the phenomenon and shed more insights into it. Interviews help to understand the perspectives and goals of people who are interviewed. The interview is a valuable way of gaining a description of actions and events- often the only way for events that took place in the past, such as completed Six Sigma projects under investigation in the current research. The researcher attempted the concept of ‘episodic interviewing’ (Flick, 2000), to enable the interviewees to retrieve their previous experience. Most of the questions related to their learning during the project execution were worded in the past tense, such as ‘‘what happened while you were stuck with some issues that needed more ideas?’’ Or with questions such as ‘‘can you explain how did you proceed further?’’. These types of questions helped access the episodic memory of the respondents. Interviewee’s responses are subject to the common problems of bias, poor recall or a poor or inaccurate articulation (Yin, 2009). In order to avoid the problem due to recollection, the interviews targeted only recent projects (previous two years), as people can recognize immediately from the recent past compared to the older events. To overcome the problem of bias and inaccurate articulations, it was decided to collect data from multiple sources for each project. Multiple sources of evidence include multiple interviewees for each project (project leader and at least two team members from each project). Throughout the interview process, the researcher followed the line of inquiry as per the protocol, asking semi-structured questions in an unbiased manner that also within the line of inquiry. In addition, extensive triangulation of data collection was employed by collecting other documented evidence about projects (Hussey and Hussey, 1997; Silverman, 2000; Easterby-Smith et al., 2012). The material evidence and observation given below helped the researcher to corroborate the interviews.

Documentation: The documents related to the projects under investigation were studied to get insights on how projects progressed. Documents such as project charters, project reports, minutes of the meetings, correspondence between other business units about projects were studied and recorded by the researcher.

Direct Observation: By making a field visit to the case study organizations, the researcher created opportunities for direct observation. The status of Six Sigma deployment at the case organizations was assessed by direct observation of some observable artifacts of Six Sigma deployment in factory floors, office displays, notice boards, deployment manager's and project leaders' offices, project control rooms etc.

Archival records: Organizational record such as organization charts, Six Sigma department activities, projects database, training schedules, certificates of specialists, project storyboards, resource planning for projects, etc.

Thus, the overall data collection for drawing evidence was not only restricted to interviews, but also other sources and the convergence of evidence was achieved from other suggested sources (Yin, 2009) as shown in Figure 8.2.



Semi-structured interviews with one leader and at least two members for each project team
At least two Senior Management team members from each organization

(Electronic recordings, Case study diary and write ups)

Archival Records: in-house publications, project data base, training records, internal documents, external published documents, project charters and related project documents- project report, minutes of the meetings, monthly reports etc.

Company documents: in-house publications, project data base, training records, notice board displays, internal documents, external published documents, project charters and related project documents. Organizational charts (Recorded, photos)

Direct Observation: Observable artefacts of Six Sigma deployment in factory, office displays, notice board, Manager's and project leaders' offices, project control room etc.

Figure 8.2 Convergence of evidence (Yin, 2009)

8.2 Case study reports

Case study reports involve maintaining a chain of evidence (Yin, 2009). The report must illustrate how the derivation of evidence from initial research questions to ultimate case study's conclusion arrives Figure 8.3 shows how the chain of evidence is observed in this research. This ensures *construct validity,* thereby increasing the overall quality of the case study. The report requires both a clear explanation of how the analysis was carried out and the conclusion was reached, as well as how the raw data was transformed into meaningful conclusions (Easterby-Smith et al., 2012).

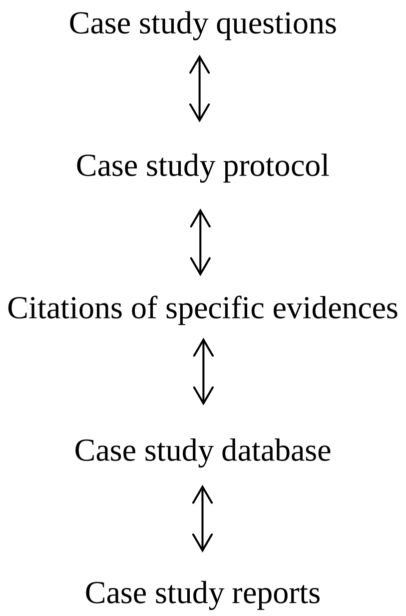


Figure 8.3 Maintaining a chain of evidence (Adapted from Yin, 2009)

For each organization, two senior management team members (deployment champion in addition to a senior management team member, either from operations or quality) were interviewed to get information about the Six Sigma deployment strategies, resources, organizations and support provided to projects. From each project, the project leader and two members were interviewed. In total, 4 senior management team members, 5 project leaders and 10 project team members were interviewed. Totally 19 interviews were held, and each interview lasted for about 60 to 90 minutes.

8.3 Data analysis

Analysis of large amounts of information gathered through the interview is the biggest challenge in qualitative research (Yin, 2009; Eisenhardt, 1989). "Analyzing data is the heart of building theory from case studies, but it is both the most difficult and the least codified part of the process" (Eisenhardt, 1989:343). In a broad sense, qualitative data analysis involves "data collection, data display, data reduction and drawing and verifying conclusions" and these steps happen concurrently (Miles & Huberman, 1994: 12). Some specific techniques are available during these steps to ensure validity and reliability which are "pattern matching, explanation building, time-series analysis, logic models, and cross-case synthesis" (Yin, 2003b: 109).

Both data reduction and data display are part of the analysis. Data reduction refers to the process of selecting, focusing, simplifying, abstracting and transforming the data from written-up field notes and transcripts. Data display is an organized, compressed assembly of information that permits conclusion drawing and action. Displays include matrices, graphs, charts and networks. Miles and Huberman (1994) suggested following analytical manipulations for data analysis, which can put the data collected in some preliminary order for easy analysis subsequently.

- Putting information into different arrays
- Making a matrix of categories and placing the evidence within such categories
- Creating data displays (flowcharts and other graphics) for examining the data
- Tabulating the frequency of different events
- Putting information in chronological order using some other temporal scheme

There is no single correct way of doing qualitative data analysis, and all these strategies are to be planned (and modified if necessary) in such a way as to fit the data one has, to answer his research questions, and to address any potentially dangerous validity threats to conclusions (Maxwell, 2013). Finally, the researcher makes conclusion from the analysis. The process followed in data analysis is shown in Figure 8.4.

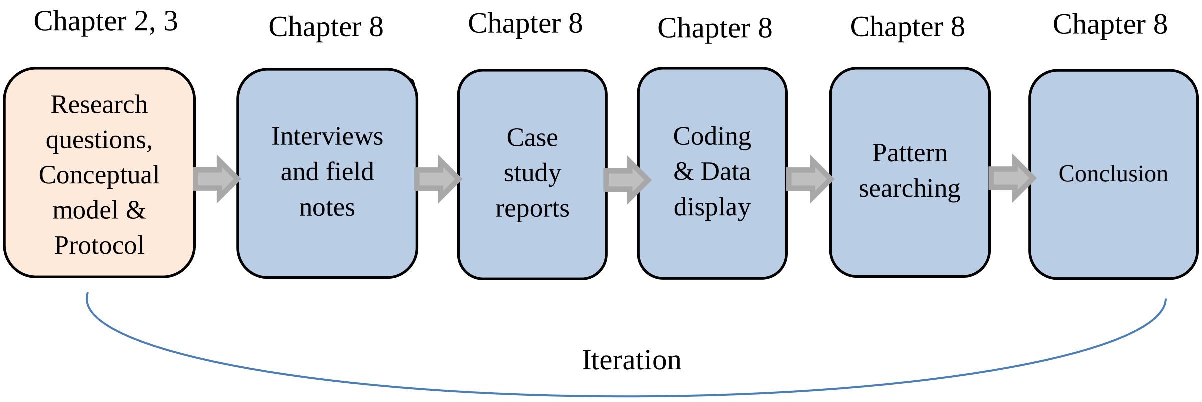


Figure 8.4 Data analysis process (Adapted from Miles and Huberman, 1994)

Eisenhardt (1989) suggests two steps in the analysis for multiple case studies: Analysis within case data and searching for cross-case patterns across cases. The primary motivation is to understand patterns in each case and to see the repeatability (if they) of patterns across cases. Replication of patterns would lead to generalizable answers to research questions. Therefore, a consistent, reliable, repeatable case study result in empirical investigation is crucial in order to answer the research questions rigorously.

In the case study research, totaling 5 cases (project), three from MFG1 and two from MFG2 are analyzed. Individual cases are analyzed and then cross-case analysis is done. The intention is to arrive at the unique patterns of each case to emerge and infer the overall findings and to explain our earlier findings of quantitative results. Thus, the principal aim is to get information on various learning practices and their antecedents and performance consequences and compare against the framework.

8.3.1 Analyzing data within cases and searching for cross-case pattern

The starting point is to construct an array or display of the data. A display is a visual format that presents information systematically so that the user can draw valid conclusions. Displays can be, as suggested by Miles and Huberman, 1994, one or more of simple arrays, event listings, critical incidents chart networks, time ordered matrices and taxonomies. For each case draw one of the above to get a pictorial display of a unique pattern, before seeking to generalize across cases (Eisenhardt, 1989). Second step is to look for explanations and causality by using one of the following techniques as suggested by Miles and Huberman, (1994):

1. Using of *Case dynamics matrix* that displays a set of forces for change and traces the consequential processes and outcomes.
2. Making a prediction and then using the case data to test them. This technique involves gathering and placing in tabular form the evidences supporting or evidences working against a prediction and examining them.
3. Using a *Causal network display* of the most important independent and dependent variables in a field study and of the relationship among them.

The systematic search for cross-case patterns is a critical step in multiple case studies to generalize the conclusions drawn from individual cases. The Primary focus is to try to look at data in many different ways (Eisenhardt, 1989). The idea behind cross-case analysis is to force investigations to go beyond initial impressions, especially through the use of structured and diverse lenses on the data. The next section explains the data analysis: coding and pattern searching within each case and across cases.

8.3.2 Display data and coding

The first step in the analysis is to read the interview transcripts, and tape recordings, observational notes, and documents collected from each site. This should be done as soon as possible after the site visit, to fill up any gaps in the data and maximize recall (Voss et al., 2002). Memos can be a valuable method for developing theory, and relate to experience with the data collected. Memos can facilitate advancing our thinking, and stimulate analytical insights (Maxwell, 2013). The next step is *coding.* While coding, similar things are grouped and categorized and given a label highlighting their similarity. Similarities and differences come to represent clusters of concepts. Comparing and contrasting, the researcher can get insights into the phenomenon. Focusing on relationships of similarity in coding is typically a *categorizing strategy* (Maxwell, 2013). By looking for antecedents and consequences, researcher can attempt to find unexpected relationships that might emerge from the data. This *connecting strategy* focuses on relationships not only between things from the data, but also among abstract concepts and categories in an actual context (Maxwell, 2013). Though both strategies are based on different forms of relationship in the data, it is possible to combine them.

Miles & Huberman (1994) suggest the following three methods for creating taxonomies that enable coding:

(1) Codes derived from the conceptual framework and the research questions

(2) Codes and the taxonomy are developed from data (commonly used method in grounded approach)

(3) Creating codes at a general level and then letting codes emerge inductively (This method is a middle approach between the above two)

The researcher used the conceptual framework and the research questions for developing codes. This also allowed the researcher to link the key components of the study with data at an early stage. Themes or concepts identified were put under three headings, as in the conceptual framework: context/antecedents, actions (learning behaviours) and results for each case. Concepts relating to managerial factors were divided into organizational and project level as explained in chapter 2. Organizational factors refer to those elements governed by the actions of managerial personnel outside the project team, and project level factors are those factors that are characteristics of projects and are mostly governed or undertaken by the project team. Table 8.1 provides the coding adopted for the two learning behaviours, knowing–what and knowing-how (developed from the literature, and explained in chapter 6).

Coding activities in this research:

1. During listening and reading, the researcher wrote notes and memos on what he saw and heard in his data, and noted tentative ideas about categories and relationships. He used the memos to categorizing and connecting strategies as suggested by Maxwell (2013). The researcher also made contextual relationships among categories and creating matrices and displays.
2. The researcher reviewed tapes and his field notes and identified data suggestive of team learning (such as questioning some aspects of team process, contacting experts from outside the team to get doubts clarified,

doing some group activities to go into deep on some aspects of the problems, discussions and generating ideas etc.).

3. Each case project is distinct in terms of types, objectives, and project goal, and hence, instances of learning may vary from team to team. The aim of the case study research is to identify learning activities that happen in teams rather than to identify the number of instances of those behaviours in teams. Therefore, it is not appropriate to count and compare the instances of learning in each team. Hence, the researcher did not make any frequency tables to count and compare instances of learning from the data. But rather his coding focused on examining types of learning practices and other factors that seem to impact learning practices and the consequences.
4. The next round of data analysis was to categorize and code the data found in step 2 into one or the other of the two learning behaviours as conceptualized in chapter 6 (activities constituting *knowing-what* and *knowing-how).*
5. By reading through the field notes, key concepts representing managerial factors (Organizational and project level) were identified by referring back to the conceptual framework, and also allowing new concepts to emerge from the data. They were coded with specific names representing their characteristics (e.g. Leadership, commitment, training, method, challenging goals etc.). If concepts did not fit in the conceptual framework, they were considered to be emergent and hence context specific to the case.
6. The codings in steps 4 and 5 were reviewed and checked by three academic experts and verified by the research supervisor.

Table 8.1 Codes for Knowing-what and knowing-how

Knowing-what	(1) Learning from other projects (2) Learning from customers/operating people (3) Learning from outside experts (4) Feedback from stakeholders/customers (5) Reflection (6) Clarification
Knowing-how	(7) Learning from within the team (8) Discussions and idea generation (9) Observation (10) Action (11) Learning by doing (12) Getting insight into the problem

(Reference: Anand et al., 2010; Edmondson, 1999; Voelpel et al., 2005; Nair et al., 2011; Harry and Schroeder, 2000; Nadler et al., 2003; Henderson and Evans, 2000;MacDuffie, 1997; Argote et al., 1999).

8.3.3 Within-case exploring, describing and explaining

Within the case analysis is driven by the research questions and conceptual framework. The aim is to explain learning behaviour and the influence that managerial factors (organizational and project level) have on learning behaviour. The data analysis has to reflect this aim. Mapping is one of the widely used visual format methods in qualitative research to provide a graphic representation of what is happening in the data. There are a number of different types of mapping such as influence diagrams, causal networks and event flow charting. As suggested by Miles and Huberman (1994), the causal network display map is used to identify the primary factors and the relationship that exists between them in this research. Concepts are denoted inside the boxes and relationships are represented by arrows or lines as shown in Figure 8.5. Here concept A is found to have an influence on concept B.

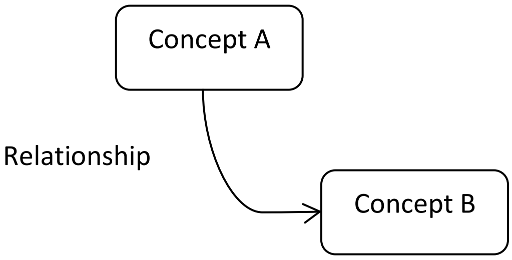


Figure 8.5 Causal network display map

A sample map is shown in Figure 8.6. The map is divided into three parts horizontally to represent: (1) Context/Antecedents, (2) Actions/Learning behaviours and (3) Results. Reading through the field notes, key concepts representing managerial factors (Context/Antecedents), learning practices (Actions/Learning behaviours) and factors denoting consequences such as knowledge and performance (Results) are entered into individual boxes and the boxes are drawn on the map under their respective headings. When the notes reveal any types of relationship between the concepts (among factors and learning practices), an arrow is drawn to represent the relationship in the map, with the direction of the arrow indicating the direction of the relationship as shown in Figure 8.6.

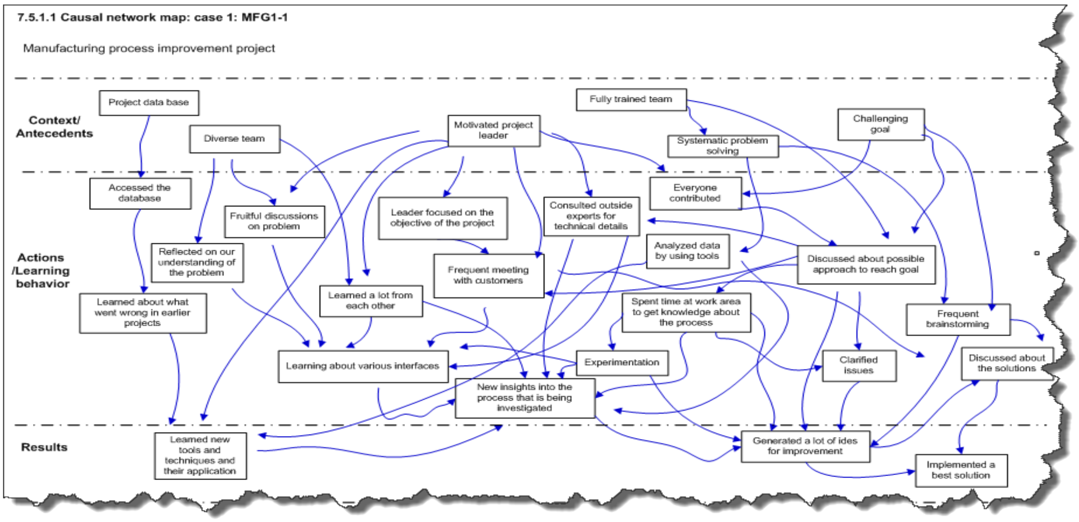


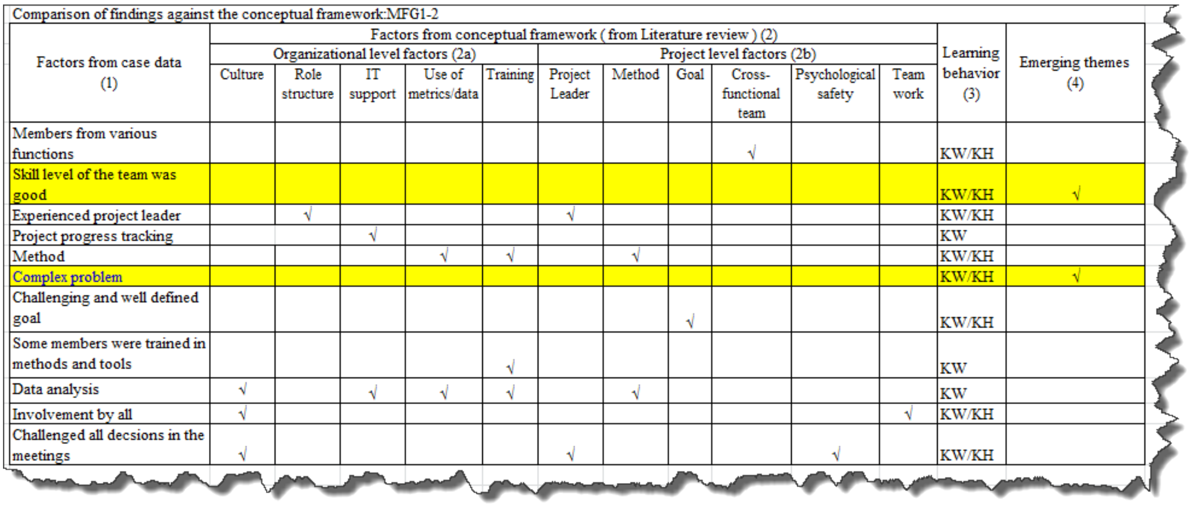
Figure 8.6 Sample Causal network display map

The causal network diagram is an important attempt at an integrated understanding of the case (Miles and Huberman, 1994). The most important factors, their interactions, and their links to the key outcome are all plotted. The maps in this research are conceptually ordered displays of the case study field notes, and information obtained from documents made available from sites. The maps allow the complex data to be presented in a visual format. The text entered in each box on the map is categorized concepts revealed from the interviews corroborated by other documented evidence. This mapping concept might be either ordered by time or ordered by concepts (Miles and Huberman, 1994). The maps presented in this chapter are conceptually ordered as they are constructed and ordered with the concepts and variables that were revealed from the interviews recorded in cases. The research questions driving this research are focused on the identification of the central concepts and the relationships between them, therefore conceptually ordering the maps is appropriate (Miles and Huberman, 1994).

A *narrative* (an analytical text) also accompanies each map. Once the maps are drawn, a detailed narrative is constructed for each map. The narrative draws attention to the features of the displayed data (map) and makes sense of them, knitting them together and permitting the analyst to draw conclusions and to aid interpretation. The role of the narrative is to provide a description and explanation of what is happening within the map, relationships that connect statement and events and therefore within a case (Coffey and Atkinson, 1996; Riessman, 1993). Miles and Huberman (1994) assert that the combination of the map and the narrative is more useful than either would be on its own. Conclusions are drawn using different tactics such as noting patterns, themes, or building a logical chain of evidence, noting relations between variables, making contrast/comparisons, and finding intervening variables. Cause analysis goes incrementally from one node to another, and researcher tests individual paths more rigorously and at the same time, building a cognitively meaningful, integrated cause map. In this analysis part, each case is analyzed using the causal network mapping technique. The aim of this technique is to identify the learning practices and managerial factors that impact learning behaviours and the relationships that exist between them. Data displays comprise of exploring and describing themes and patterns.

The next step in the data analysis is to compare the findings of each case against the conceptual framework and provide explanations. The findings of each case are summarized in an *effect matrix,* which helps to compare the findings with the conceptual framework. A sample effect matrix is shown in Figure 8.7. The entries in column 1 of the table are concepts taken from the map under the heading ‘context/antecedents’, and ‘Actions’ which are found to cause learning practices. Column 2 carries factors from the conceptual framework, with organizational factors under sub-column 2a and project level factors under sub-column 2b. Column 3 contains learning behaviours (either Knowing-what (KW) or Knowing-how (KH)) that are associated with the respective entries in column 1. Learning practices from the map is codified as KW or KH by using the coding from Table 8.1. Column4 shows the emerging themes.

Each entry in column 1 are checked for their associations with either the organization or the project level factors of column 2. If an association is found between them, a tick mark (√) is entered into the intersection cell (cell at the intersection of the row and column). In Figure 8.7, for example, 'experienced project leader' (entry in column 1 and row 3) is associated with 'role structure' from column 2a. Accordingly, a tick mark (√) is entered into the intersection cell which appears in the row containing 'Experienced project leader' under the 'Role structure' column. If any of the concepts in column 1 does not find any association with any of the factors from the conceptual framework, it is considered as emergent. It is marked with a tick mark under 'emergent theme' in column 4. The emergent theme row is highlighted in yellow for identification purpose. Each case analysis, then concludes with a summary of findings.



Comparison of findings against the conceptual framework:MFG1-2

Factors from case data (1)	Factors from conceptual framework (from Literature review) (2)											Learning behavior (3)	Emerging themes (4)
	Organizational level factors (2a)					Project level factors (2b)							
	Culture	Role structure	IT support	Use of metrics/data	Training	Project Leader	Method	Goal	Cross-functional team	Psychological safety	Team work		
Members from various functions									√			KW/KH	
Skill level of the team was good												KW/KH	√
Experienced project leader		√				√						KW/KH	
Project progress tracking			√									KW	
Method				√	√		√					KW/KH	
Complex problem												KW/KH	√
Challenging and well defined goal								√				KW/KH	
Some members were trained in methods and tools					√							KW	
Data analysis	√		√	√	√		√					KW	
Involvement by all	√										√	KW/KH	
Challenged all decsions in the meetings	√					√				√		KW/KH	

Figure 8.7 A sample Effect matrix

8.3.4 Verification of the interpretation of within case analysis

The coding of the transcripts and pattern searching were peer reviewed by three academic experts from the University and ensured the agreement on coding and categorization. The procedure involved first independent coding of the transcripts and then comparing and discussing codings and themes until an agreement was reached. Respondents' checking was conducted to ensure the accuracy of the recorded data and presentation of participants' views (Lincoln & Guba, 1985). So, the researcher sent the maps and the narratives to each project leader through the contact person from the two case companies, with a request to verify the accuracy of the reports and maps. The project leaders were also asked to discuss with the other team members who were the respondents. Although most confirmed the accuracy of the recording, maps and narratives, some participants clarified their views and the meaning of some comments made during their interviews. Thus, most of the interpretations were found to reflect that of the teams, with some changes to a few arrows as suggested by the respondents, which were then incorporated in the final maps. In summary, the maps and narratives are found to be reflecting the cases objectively.

8.3.5 Cross-Case Displays

The main purpose of Cross-Case analysis in this research is to enhance the generalizability of the findings if any. The second, more fundamental reason is to deepen understanding and explanation of the learning process in Six Sigma process within various projects in their respective contexts. Finally, cross-case analysis can also increase the internal validity of the findings as informed by Voss et al. (2002).

The approach considers the case as a whole entity and looking at configurations, associations, causes, and effects of the case and then turns to comparative analysis of other cases. In this analysis, the researcher looks for underlying similarities and constant associations, compare cases with different outcomes, and begin to form more general explanations (Miles and Huberman, 1994). The typical starting point for analysis is to construct an array of systematically displayed data and then the researcher should begin looking for an explanation and causality (Voss et al., 2002). Miles and Huberman (1994) outline the following two approaches for effectively doing Cross-Case analysis:

Case-oriented strategy
Variable-oriented strategy

In case-oriented strategy, common base considered is a conceptual framework. One case is studied in depth and then successive cases are examined to see whether the pattern found matches that in the previous case. In a variable-oriented strategy, on the other hand, researchers often look for themes that cut across cases. Depending on the research aims of the study, the strategies can be adopted together or singularly on their own.

In this research, both the strategies have been used. In the case-oriented analysis, the conceptual framework is used to compare the findings across all the cases. This is in line with Yin (2009) who stated that data analysis should rely on the theoretical propositions that led the case study in the first instance. The use of the conceptual framework, often, focuses attention on particular data, leaving or ignoring other data. Hence, the researcher decided to use a method that combines both the conceptual framework and the case data to draw conclusions about the overall cases. Although the case-oriented analysis is focused on the *a priori* concept, using this with the variable-oriented analysis allows emergent themes to be investigated across the cases.

Network drawn for each case is in some senses unique, a narrative of what happened in each case. We need to find a generic narrative model and explain through analysis of multiple cases. A real explanation be reached by going back and forth between, or synthesizing, two strategies aimed at understanding *case dynamics* and at seeing the effect of key *variables* (Miles and Huberman, 1994).

Making use of the conceptual framework developed in chapter 3 and the case data (both the raw data and the causal network maps developed from the within case analysis), the causal links that surround the organizational factors and learning behaviour in Six Sigma project teams will be explained. This explanation building process not only helps to draw conclusions from the study, but also can help generate hypotheses where the aim is not to draw conclusions but to develop ideas for further study. In the following sections, the mapping exercise will be performed for each case study.

As the aim of the qualitative study is to identify all learning practices and their context and antecedents as evidenced from the five cases, in the analysis phase of the study, the researcher will generate factors from the cases. For a single case study, making a list is fairly straightforward. For a multiple case study, some variables may be empirically meaningful to individual specific cases. Therefore, the list may contain (a) common variables that are influential in most but not all cases and (b) case-unique variables. These variables include both the variables that appear in the conceptual framework and the ones that may emerge from the cases. Finally, for each case, the findings will be compared with the conceptual framework. The factors identified from the map that relate to the conceptual framework (identified from the literature review) will be considered as *deductive factors* and the new factors as *emerging factors*. The next section will explain the empirical findings through case data analysis.

8.4 Empirical findings: within-case analysis

This section describes the findings gathered from the empirical case study and data analysis part of the qualitative research phase. Each case study is introduced, and the within case analysis for each case is presented. As discussed in the previous chapter, the finding of each case is presented as maps. As mentioned earlier, the maps are conceptually ordered displays of the case study notes showing the relationship between concepts visually (the linkage of context/antecedents-actions/learning practices-results). Each causal map is followed by a narrative analysis and an effect matrix. Narrative analysis is the description of the map discussing the relationship between the concepts. The effect matrix is a chart showing various factors identified in the case and their relationship with the learning behaviours identified in the case. The effect matrix also shows various factors from the conceptual framework and how they are compared with that of the case findings. Each case concludes with a summary of key findings. Figure 8.8 outlines the steps involved in presenting case analysis.

Cases: Our unit of analysis is Six Sigma project, and the embedded unit of analysis is learning behaviours in project teams. Projects with wide variations in type, objective, team composition and nature of projects were selected as cases for the research. Technical details of the individual projects will not be discussed as per the agreement with the participating companies, but rather, general information and those related to learning in each case will be discussed.

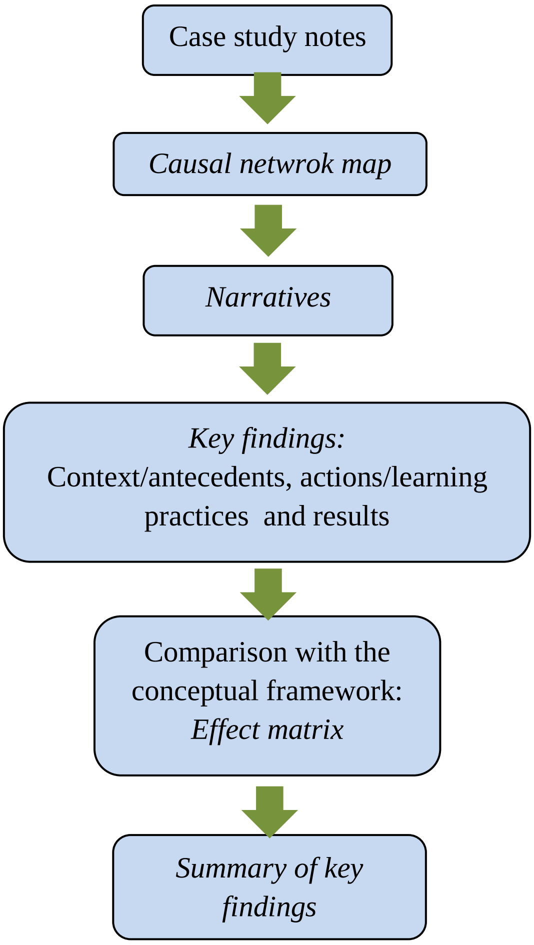


Figure 8.8 Structure of within case analysis

(Adopted from Miles and Huberman, 1994)

The following sections from 8.4.1 to 8.4.5 describe each case in brief followed by the causal network map, narratives, effect matrix (comparison with the conceptual framework), key findings and summary of each case, and emergent factors of the case, if any.

8.4.1 Case 1 analysis

Case 1: MFG1-1

Problem: In manufacturing, some of the products undergo grinding operations that use abrasive grinding wheels made up of either conventional abrasives (Silicon

Carbide, Aluminium Oxide or Ceramic grains) or super abrasives (Diamond or Cubic Boron Nitride: Borazon). Super abrasive wheels are used for harder materials, and they are costlier. Of late, the management found that the consumption of the grinding wheel and the cost were on the increase, which attracted the management attention.

Project Goal: To increase the lifetime of abrasive grinding wheel by 40%. The grinding wheel is used for grinding parts made up of hard super alloy material.

Project leader: Black Belt, who has completed 5 Six Sigma projects

Project team: 6 members including the project leader. Members represented manufacturing, tool engineering, quality, procurement, and production engineering. All had basic skills in Six Sigma method and tools.

Project duration: 6 months

The Performance achieved: Achieved the project goal within the project schedule. Changed implemented includes operating procedures, machine setting procedures, changes in the grinding wheel specifications, changes in the operating conditions.

8.4.1.1 Causal network map

Figure 8.9 shows the causal network map for the case MFG1-1. Boxes are drawn with the respective concepts or factors such as context/antecedents, actions, learning practices and results. Arrows are drawn as explained in the previous section.

8.4.1.1 Causal network map: case 1: MFG1-1

Manufacturing process improvement project

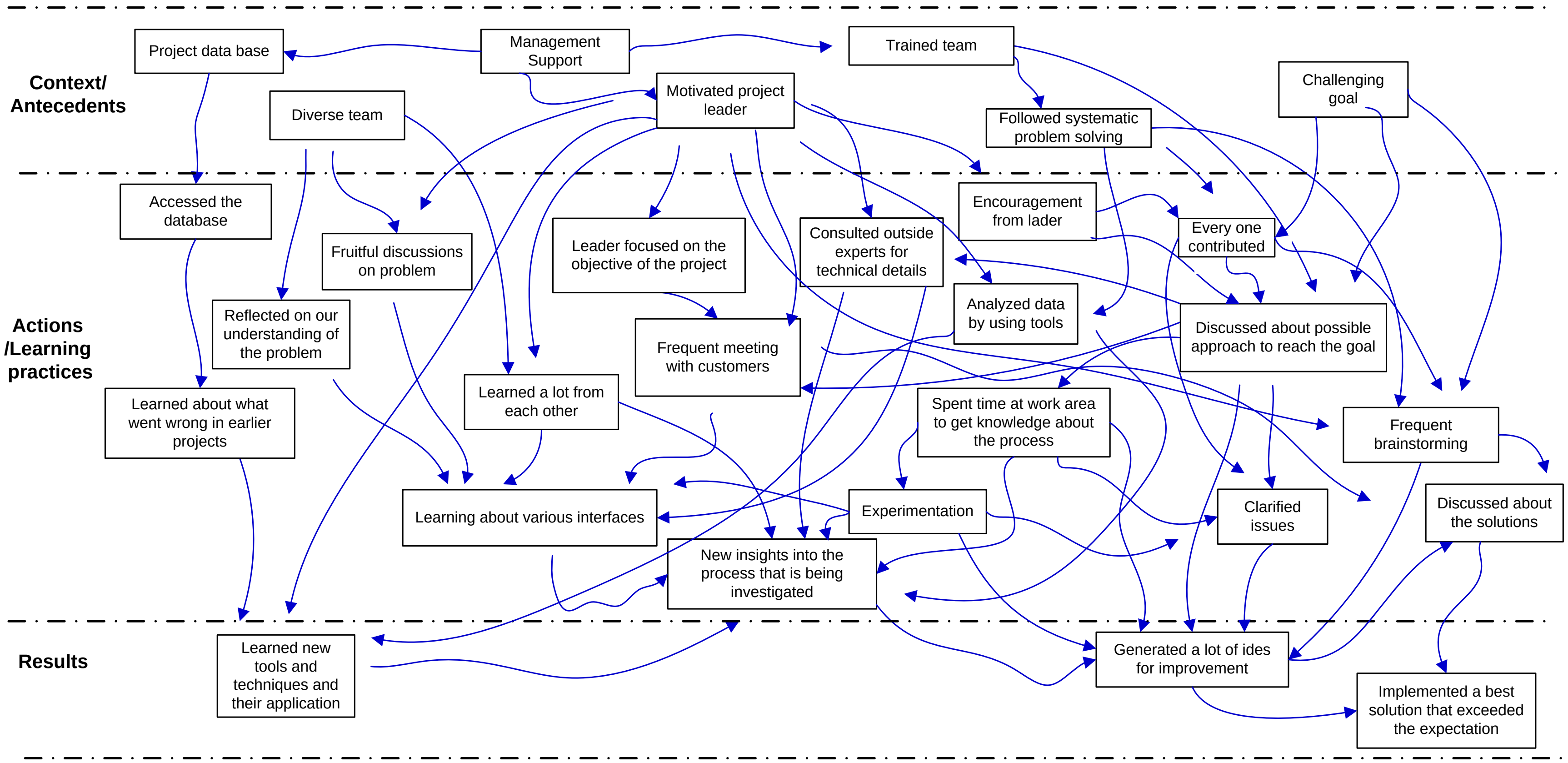


Figure 8.9 Causal network map: case 1: MFG1-1

8.4.1.2 Narratives: case 1

The project team had an experienced and highly motivated project leader and members came from various functions related to the problem. The skill level of the team was also found to be sufficient for carrying out the project without much difficulty. As the team members are from various functional departments that are related to the project, the team often had fruitful discussions and shared their knowledge leading to a better understanding of the problem. Member's learning from each other led to a better appreciation and understanding of various interfaces and see the problem in its total perspective.

Team accessed the company's Six Sigma database and referred to similar projects from other business units and learned about what went wrong in other projects and what made the project’s success. These learnings helped team to plan and execute the current project in more appropriate ways. This also helped them learn some new tools which were required to be applied to the current project. With the help of the project leader, members at times, learned and acquired some skills in these new tools. The team analyzed data by using various tools that helped to gain insights into the problem.

The project leader's motivation level was highly rated by all team members. The leader highly focused on the objective of the project, and this led each meeting to benefit from fruitful discussions. He was also found to encourage all members' participations resulting in maximum contributions from them. Frequent meetings, discussions and the work spot visits and observations thereon carried out by the team helped clarify a lot of issues that came up in the meetings, and reflect their findings and suggestions. Project leader also encouraged frequent meeting with the operating people (customers) that helped getting some insights into the problem and consequences. He also used to encourage consultations with outside experts from grinding wheel manufacturers, which helped the team gain more technical input for moving forward. The findings also revealed that team’s project execution are primarily through leader’s activities in gathering knowledge and creating knowledge.

The challenging goals motivated the team to have a multiple numbers of discussions on possible approaches to reach the goal. The team had a number of brainstorming sessions and spent a lot of time in the plant to learn about the problem.

The team conducted a number of experiments on various options they planned based on the data analysis. These helped them generate a number of ideas for improvement and finally implement a best solution that optimized the lifetime of the grinding wheel.

8.4.1.3 Comparison with the conceptual framework

Table 8.2 summarizes the findings of case 1, which shows the factors, learning behaviours and how the results compare with the factors of the conceptual framework, organizational and project level factors. Based on the association of the factors in each row of column 1 with the factors of column 2 (a and b), tick marks are entered in the appropriate intersecting cells. In column 3, corresponding learning behaviours, either or both of KW and KH (knowing-what and knowing-how respectively) are entered based on the coding. As all factors from column 1 have one or more tick marks along their individual rows against the factors of column 2, it is understood that there are no emergent factors of this case. Accordingly, the emergent theme column 4 is left blank. All factors of the conceptual framework are evidenced in this case data.

Table 8.2 Comparison of findings against the conceptual framework: Case 1 MFG1-1

Factors from case data (1)	Factors from the conceptual framework (from Literature review) (2)											Learning behaviours	Emerging themes (4)
	Organizational level factors (2a)					Project level factors (2b)							
	Culture	Role structure	IT support	Use of metrics/data	Training	Project Leader	Method	Goal	Cross-functional team	Psychological safety	Team work		
Senior management involvement and support		√	√		√							KW	
Consulting the project database			√									KW	
Diverse team									√			KW/KH	
Motivated team leader		√				√						KW/KH	
Systematic problem-solving				√	√		√					KW/KH	
Data analysis	√		√	√	√		√					KW	
A challenging goal								√				KW/KH	
Fully trained team		√			√							KW/KH	
Encouragement by project leader						√				√		KW/KH	
Contribution by all in discussions and meetings											√	KW/KH	

8.4.1.4 Key findings and summary of case 1

Context and antecedents:

Management support and involvement

Project database

Diverse team

Motivated team leader

Systematic method

A challenging goal

Trained team

Data analysis

Encouragement by project leader

Contribution by all

Learning practices:

Knowing-what: Learning from other projects
    Learning from customers
    Learning from outside experts
    Reflections on understanding
    Data analysis
Knowing-how: Discussions and brainstorming
    Learning from each other
    Observation
    New idea generation
    Clarification
    Experimentation
    Learning the causal relationship between factors

Results:

Generated a lot of ideas

Cost savings achieved

Exceeded the project goal

Emerging themes and factors: No new factors emerged from this case.

8.4.2 Case 2 analysis

Case 2: MFG1-2

Problem: The project focused on the lead time of a newly traded special product for a new automobile. The customer (an automobile vehicle manufacturer) wanted the lead time to be shortened by 45%, as he expected a huge volume increase for the vehicle model, and he wanted to shorten the lead time of the product's supply chain. The products are to reach multiple locations (US and Europe). Management of the MFG1 felt that the optimization of production at various sites and supply chain processes would provide a stable improvement in the lead time. The project was *complex*, having more number of department interfaces (manufacturing, supply chain, production control, logistics, quality, marketing, sales, and finance) and their complex interactions.

Complexity in process improvement projects such as Six Sigma project can be characterized by two dimensions: number of variables and or their complex interactions acting on the problem. Accordingly, we have size complexity or interaction complexity (Sommer and Loch, 2004; Baccarini, 1996). The complex processes are likely to have more geographic spread, wider interfaces with a number of processes, and hence have multiple variables interacting and influencing on the outcome variable (Nair et al., 2011). Complexity then, is a measure of the inherent difficulty to achieve the desired understanding of the process. It needs additional efforts on the part of the team to collect relevant data and analysis to understand the complexity of the entire process, as it involves a huge data (technical and managerial) from multiple sources and associated with a huge data analysis.

- *Project goal:* To reduce lead time for the newly traded product for a strategic prime customer. Well defined project goal that aimed to reduce the lead time by 45%. (From 40 days to 22 days).
- *Project leader*: Black Belt (well experienced in Six Sigma projects)
- *Project team*: 7 members. Four members have experience in previous projects, and the rest of the team has recently undergone training, and hence knowledge of method and tools. One member was from the finance function.
- *Project duration*: Initial goal was to complete the project within 5 months

- *The performance achieved*: The team reached the project goal, but the project duration was extended by two months, due to enormous tasks that the team had to carry out, both during problem-solving and implementation.

8.4.2.1 Causal network map

Figure 8.10 shows the causal network map for the case MFG1-2. Boxes are drawn with the respective concepts or factors such as context/antecedents, actions, learning practices and results. Arrows are drawn as explained earlier. The following section will explain through a narrative.

8.4.2.1 Causal network map: case 2: MFG1-2

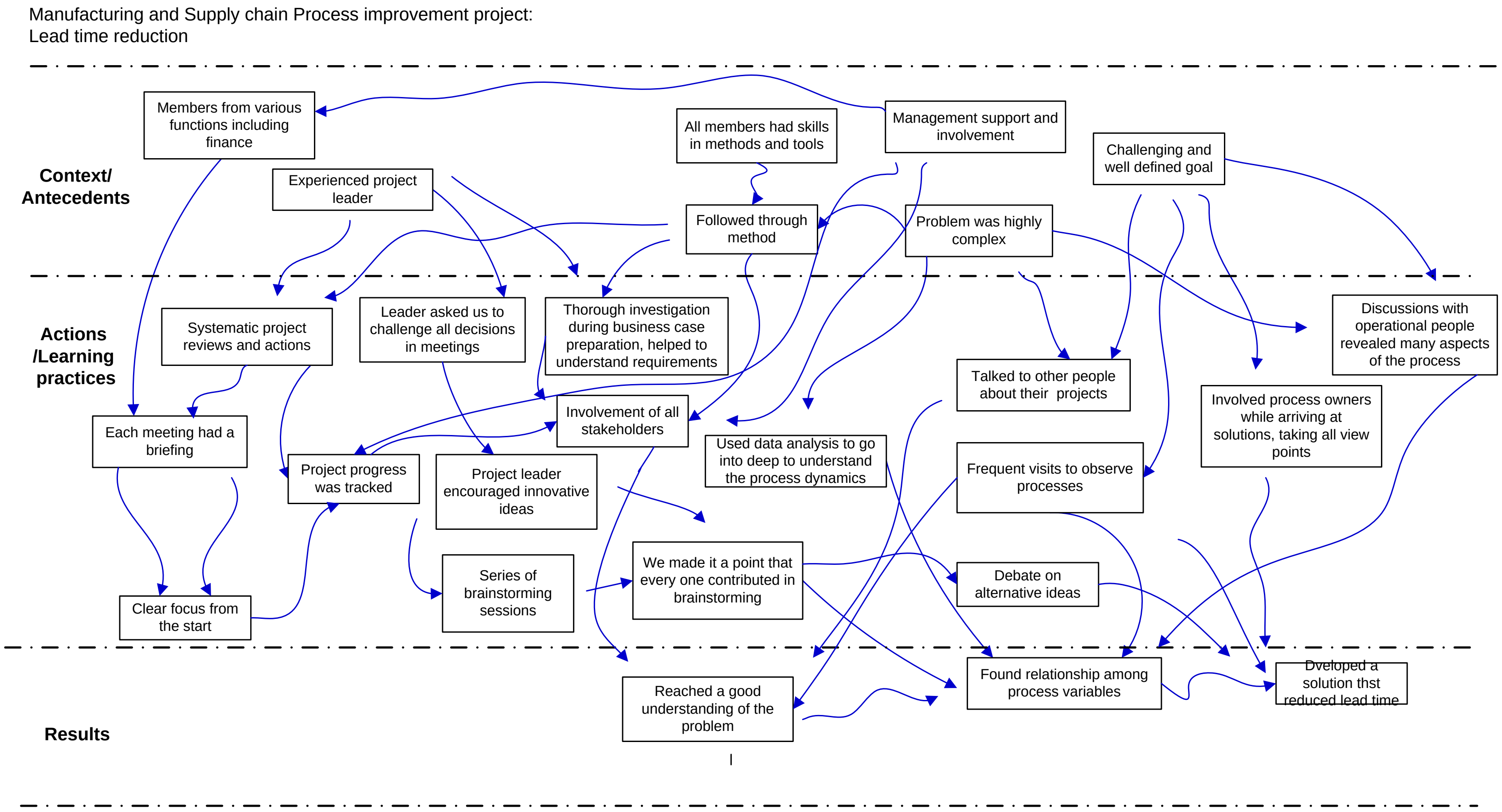


Figure 8.10 Causal network map: case 2: MFG1-2

8.4.2.2 Narratives

The project team had an experienced project leader and members came from various functions. The skill level of the team was fairly good at problem-solving. The project was highly complex, involving multiple numbers of functions and activities. The project goal was highly challenging, well defined and specific. As the members were from various functions, they were given different responsibilities in the project execution. In each and every meeting, leader used to have a briefing on what had happened and where the team was leading to. This resulted in clear focus right from the beginning that helped them track the project and move in the right direction. Since all members had a certain level of skills in methods and tools, the team could carry out the project, in spite of the complexity of the project.

Right from the beginning, the team had a clear focus on its approach and actions toward understanding various aspects of the process under investigation. While preparing business cases, the team carried out an in-depth inquiry into the entire process, using various tools such as process flow chart, detailed process map, including Supplier-Input-Process-Output-Customer (SIPOC) map. Leader encouraged innovative ideas from the members, asked them to challenge each and every decision taken in the course of the project execution. The team had a series of brainstorming sessions, and all members were encouraged to participate in team activities. The map reveals (based on quotes) that the adherence of method is primarily due to project leader’s behaviour. He encourages knowledge building to solve problems by using various techniques as embedded in DMAIC methodology.

The team used statistical tools to investigate the causal relationships between antecedents and process outcome. This resulted in establishing a causal relationship between variables. The team also had some interactions with people from outside regarding the project and team got information and knowledge that helped solve the problem. The team made frequent visit to the work spot and observed the process and discussed with process personnel to get more knowledge about the process. The discussions with process people could help them for increased understanding of the requirement, problems, and interfaces and that resulted in a good working relationship with process people.

The Challenging goals coupled with the project complexity made the team go in for more learning cycles. More and more people relating to the project were interacted for possible information and knowledge to enhance the project success. When the solution was identified by the team, the team discussed with the process people about various consequences and got their viewpoints. Thus, the team had a series of actions and reflection cycles. Finally, the team could get detailed knowledge about the process, and develop and implement a high-impact solution that reduced lead time.

As the problem was complex in nature, the team resorted to more learning, using advanced tools and techniques for problem solving, and discussions with other project teams to get advices and suggestions for possible approaches. In addition, the complexity of the problem led them to have more frequent discussions with process people. Further, the interaction levels both within and outside the team was also found to be high. Overall, the team came out with an excellent solution that exceeded the project goal initially set, although the project took additional time to complete the project.

8.4.2.3 Comparison with the conceptual framework: case 2

The data analysis revealed that the project was highly complex. The number of departments involved in the projects was more than seven, and their interactions were complex, leading to complex data analysis. The team had to make efficient planning, coordination and control of their actions in order to complete the project successfully. This greatly impacted their learning cycle-involvement of all stakeholders, strictly adhering to systematic project execution, getting information from all related people and functions, systematic data collection and analysis, clear focus right from the start, etc. Table 8.3 summarizes the findings of case 2 that compares the results with the conceptual framework.

Two new factors have emerged from this case that have influences on learning: *Project complexity* and *team's skill level*. Both these factors are the project level factors. As the skill level was quite adequate within the team, the team could learn to match the complexity of the project. Highly challenging goal motivated the team to take extra efforts toward learning about the various functions and their interactions and solve the problem. The team skills helped overcome the difficulties faced by them. Thus, the skill level of the problem and complexity are the two contextual project level factors emerged from this case.

8.4.2.4 Key findings and summary of the case 2

Context and antecedents:

Management support and involvement
Members from various functions
Skill level of the team
Experienced project leader
Project tracking
Method
Data analysis
Complex problem
Challenging and well-defined goal
Trained members
Involvement of all
Members challenging decisions in meetings

Learning practices:

Knowing-what:	Learning from the process and operating people
	Learning from other projects
	Feedback from customers
	Discussions with outside people
	Reflection
	Clarification
Knowing-how:	Action
	Learning by doing
	Discussions and idea generation
	Observation
	Learning from within the team
	Insights into the problem

Results: (project outcome)

Improvement in lead time of the process

High impact solution achieved

Emerging themes and factors

New concepts of *project complexity* and *team's skill level* emerged from this case.

Table 8.3 Comparison of findings against the conceptual framework: Case 2 MFG1-2

Factors from case data (1)	Factors from the conceptual framework (from Literature review) (2)											Learning behaviours	Emerging themes (4)
	Organizational level factors (2a)					Project level factors (2b)							
	Culture	Role structure	IT support	Use of metrics/data	Training	Project Leader	Method	Goal	Cross-functional team	Psychological safety	Teamwork		
Senior management involvement and support		√	√		√							KW	
Members from various functions									√			KW/KH	
The skill level of the team was extremely good												KW/KH	√
Experienced project leader		√				√						KW/KH	
Project progress tracking			√									KW	
Method				√	√		√					KW/KH	
Data analysis	√		√	√	√		√					KW	
A complex problem												KW/KH	√
Challenging and well-defined goal								√				KW/KH	
Members were trained in methods and tools					√							KW	
Involvement by all	√										√	KW/KH	
Challenged all decisions in the meetings	√					√				√		KW/KH	

8.4.3 Case 3 analysis

Case 3: MFG1-3

Problem: In order to have a high degree of supply chain performance, management decided to focus a number of things relating to supplier relationship. One of the focused areas was to enhance the satisfaction level of all strategic suppliers with respect to contract and agreement. It was expected that this would lead to cordial business relationships, cooperation, collaboration, and transparency. The organization has a '*De-satisfaction*' index for measuring the satisfaction level of various supplier relationships. As a strategic initiative, the management wanted to enhance the supplier relationship for better performance in supply chain management. The team felt that the project faced uncertainty in terms of being not aware of the various factors that need to be considered and their functional relationships which impact the project outcome.

Uncertainty in the context of Six Sigma projects, refers to the inability to recognize and articulate all influencing variables and their interactions and functional relationship at the outset (Sommer and Loch, 2004; Schrader et al., 1993). The core of the idea of uncertainty is the idea that information is incomplete concerning the attributes, causes, or effects of the phenomenon of interest (Sitkin et al., 1994). In overall, uncertainty refers to the lack of certainty- uncertainty of outcome and lack of clarity on situational factors affecting the project (Nair et al., 2011). Uncertainty is the intangible measure of what the project team does not know about the variables underlying the project and their interactions and relationships with output. But, during the course of the project, the team may overcome all these difficulties and come out with success at the end. This only requires relentless efforts on the part of the team to dig into the problem and seek for various aspects of the project and take action to overcome all the difficulties. Managing uncertainty depends, hugely on how much the team is able to understand the realities of the situation, and developing an awareness of what is known, and to some extent what is unknown (Cledon, 2009).

- *Project goal*: Improve supplier De-satisfaction index of 39 to 19 for the 136 strategic suppliers
- *Project leader:* Black Belt (Dynamic and encouraging project leader)

- *Project team*: 7 members (Legal, Supplier quality development, Procurement, account payable, strategic sourcing)
- *Project duration*: 6 months (extended by a month)
- *The Performance achieved: A D*e-satisfaction level of 20 was achieved during the first evaluation. A number of guidelines introduced in various departments.

8.4.3.1 Causal network map

Figure 8.11 shows the causal network map for the case MFG1-3. Boxes are drawn with the respective concepts or factors such as context/antecedents, actions, learning practices and results. Arrows are drawn as explained earlier. The following section will explain through a narrative.

8.4.3.1 Causal network map: case 3: MFG1-3

Supplier satisfaction level improvement

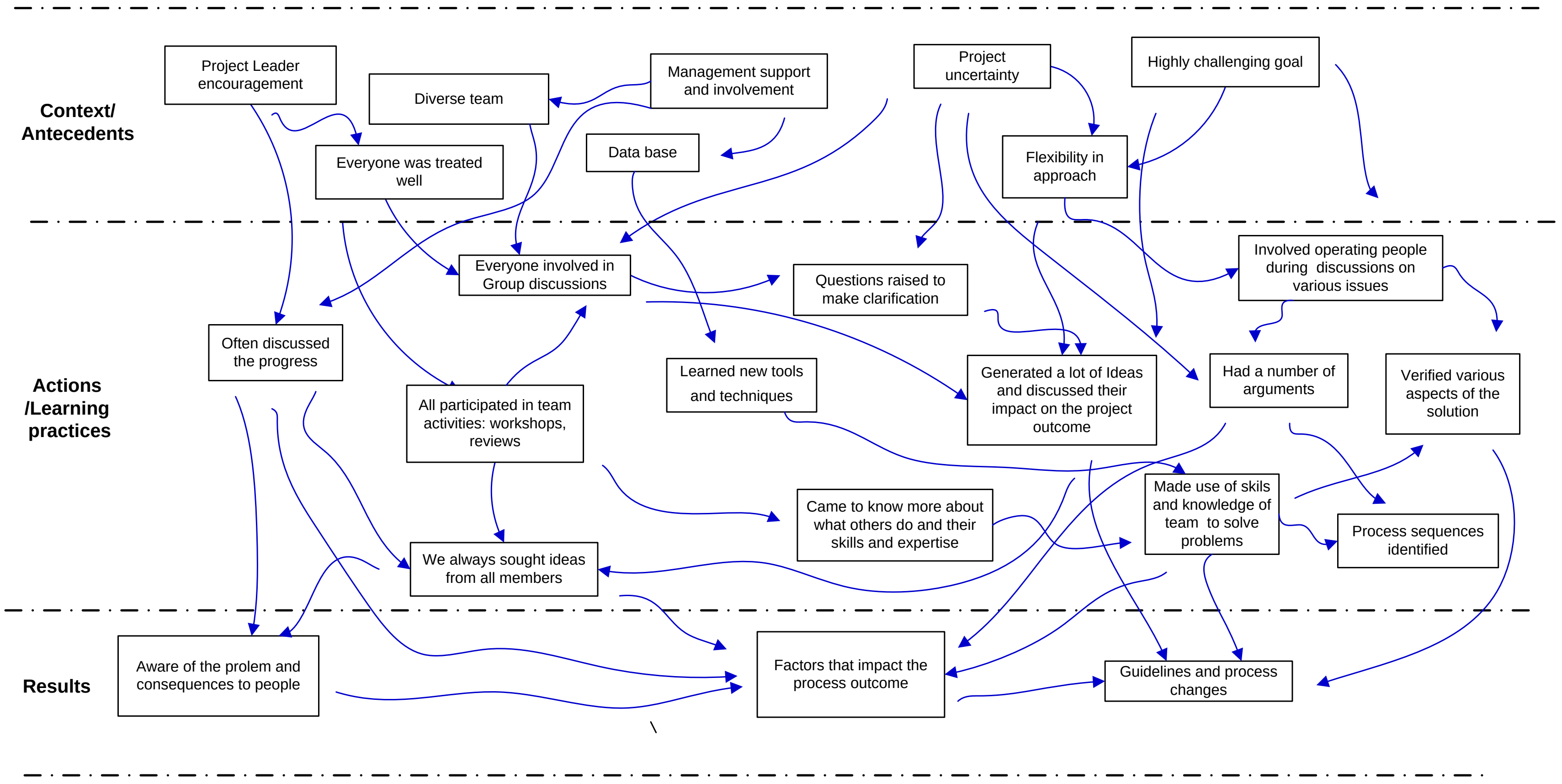


Figure 8.11 Causal nētwork map: case 3: MFG1-3

8.4.3.2 Narratives

The project team came from diverse functions and had an encouraging project leader. Being a proactive leader, he often initiated the meetings to discuss the progress of the project. He treated everyone equally, and that helped everyone in the team involve and participate in team activities. Further, this helped create a healthy environment that is conducive to knowledge transfer among members and generate a lot of ideas for improvement in team meetings. This also provided an atmosphere conducive for raising questions and making clarification. In addition, team diversity facilitated the everyone's involvement and participation in discussion. Team participation was very high, but it was found that the team skipped some of the steps in DMAIC cycle.

Initially at the start of the project, the team felt uncertainty, as they were not having enough knowledge and clarity about various departmental functions that need to be involved and their relationships. They, therefore, did not know any clue about what data to be collected, and what issues to be considered as essential for improving the process to reach the goal. This went on for a while, and subsequently, this led to the deployment champion coming to their rescue. Due to the strategic nature of the project coupled with its uncertainty, deployment champion frequently involved and provided support for the project. The team had a large number of meetings to discuss, agree with stakeholders, and for a focused analysis of the past data. This further led the team to seek ideas and suggestions from stakeholders, and that ultimately brought the team to a better position in identifying the optimal solution for implementation across different functions. The highly challenging goal, motivation of the project leader and the timely support from the management made the team finally worked on the project. It was also revealed from the case data that the team had a flexible approach to conducting the project. The team also involved a number of people from different stakeholders and discussed the impact on them and verified the solution along with the stakeholders.

At the meetings, questions were raised to make many clarifications. Team leader encouraged arguments from members. The team used each one's talent and skills throughout the project execution. The team came to know about other's skill and knowledge and accordingly they could mobilize and use appropriate skills to the various facets of project implementation (data analysis, taking up any matter with other stakeholders, contacting people for expertise, conducting trials, talking to other regions of the business for possible information and actions, etc.). The team had a number of discussions to identify the impacts of the solutions on the project outcome. The team came to know the details of the problem and its consequences which led them to focus on all the factors that affect the project outcome. The team finally arrived at an optimal solution.

8.4.3.3 Comparison with the conceptual framework

Table 8.4 summarizes the findings of case 3 that compares the results with the conceptual framework. One new factor that has emerged from this case that has influence on learning is *project uncertainty*, an organizational factor. In addition, the team lacked clarity on the contextual factors at the outset. The uncertainty created some disruptions and anxiety among the members, making the senior management team to step in and induced constructive collaboration and contribution among members. Project leader’s encouragement helped move forward through learning and knowledge transfer. The situation arising out of the uncertainty has increased cooperation and collaboration among team members apart from seeking support from stakeholders. The team tried to put extra efforts to learn and understand the realities of the situation to become successful. Only during the later part of the project execution, the team became confident of their knowledge about the process and factors and interfaces. The team tries to put all out their efforts to learn what is known and known. This ultimately affected the project duration and to a certain extent project outcome.

Table 8.4 Comparison of findings against the conceptual framework: Case 3 MFG1-3

Factors from case data (1)	Factors from the conceptual framework (from Literature review) (2)											Learning behaviours	Emerging theme (4)
	Organizational level factors (2a)					Project level factors (2b)							
	Culture	Role structure	IT support	Use of metrics/data	Training	Project Leader	Method	Goal	Cross-functional team	Psychological safety	Team work		
Senior management involvement and support		√	√		√							KW	
Project Leader encouragement		√				√						KW/KH	
Diverse team									√			KW/KH	
Project uncertainty												KW/KH	√
Highly challenging goal								√				KW/KH	
Flexible approach (method)					√		√					KW/KH	
Tools and techniques	√		√	√	√		√					KW	
Everyone was treated well										√		KW/KH	
Everyone's skills were utilized				√						√		KW/KH	
Involvement & participation by all	√										√	KW/KH	

8.4.3.4 Key findings and summary of the case 3

Context and antecedents:

Management support and involvement
Project leader
Diverse team
Project uncertainty
Challenging Goal
Method
Tools and techniques
Everyone was treated well
People raised questions in meetings
Involvement and participation by all

Learning practices:

Knowing-what:	Learning from the process and operating people Learning from other projects Learning from outside experts Reflection Clarification
Knowing-how:	Action New idea generation Learning by doing Discussions and idea generation Learning from within the team Observation Getting insights into the problem

Results (Project outcome):

Learned people oriented issues
Process Optimized
Guidelines and process changes

Strategic impact was high

Emerging themes and factors

A New concept of *project uncertainty* emerged from this case. Interaction levels both within and outside the team were high leading to more learning. In addition, when the project team faced uncertainty, senior management involved ensuring that the project moves smoothly.

8.4.4 Case 4 analysis

Case 4: MFG2-1

Problem: Heavy duty Gearbox used in wind turbine is manufactured in a factory in Europe and is transported to rest of the world. It weighs about 24 tons. The cost of transport (sea- worthy packing, transporting to port and sea transport to the respective countries) for transporting about 100 gear boxes each year is roughly about 2 million Euro.

The project had a wider geographic spread and had to deal with a number of departments within the company, several transport agencies, various sea-transport regulations, and their complex interactions both technical and political. The team needed to study a number of new things about the projects. Thus, the project was highly complex.

- *Project goal:* 40% reduction in transportation cost
- *Project leader*: Experienced project leader
- *Project team*: 5 members (transport & logistics, technology, lifting equipment designer, production coordination, and production)
- *Project duration*: Planned duration six months (extended by more than two months)
- *The performance achieved*: 42% cost reduction achieved (a cost effective and environmental friendly sea-transport packing system that satisfies sea transport regulation, gear box manufacturer’s guidelines, and all technical requirements; streamlined logistics and standardize procedures, reduction of manpower used, and elimination of packing sub-contractors.

8.4.4.1 Causal network map

Figure 8.12 shows the causal network map for the case MFG2-1. Boxes are drawn with the respective concepts or factors such as context/antecedents, actions, learning practices and results. Arrows are drawn as explained earlier. The following section will explain through a narrative.

8.4.4.1 Causal network map: case 4: MFG 2-1

Improvement in packing and transportation

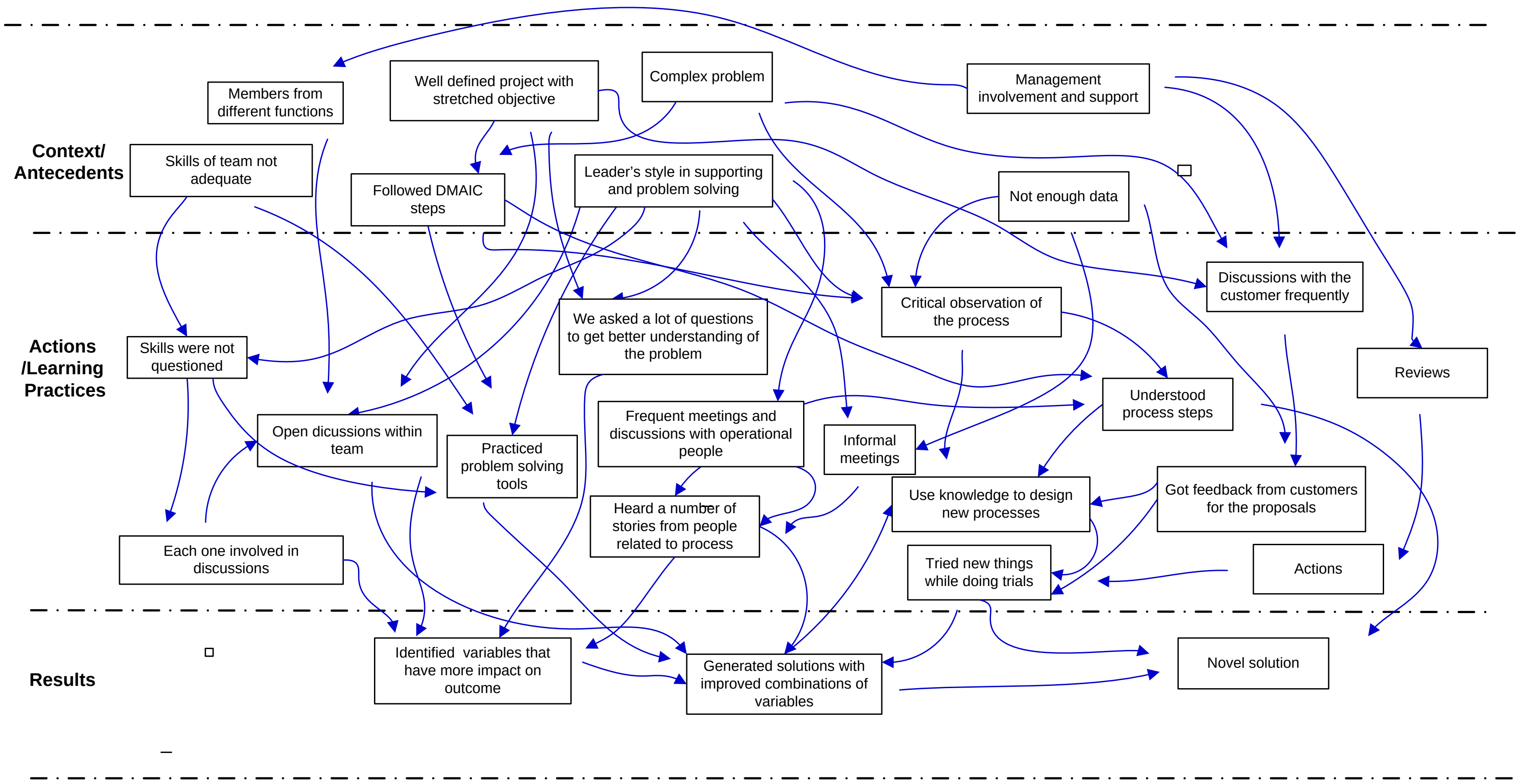


Figure 8.12 Causal network map: case 5: MFG 2-2

8.4.4.2 Narratives

The Goal was challenging. The leader had vast experience in Six Sigma projects. He used his knowledge gathering behaviour to enhance the effectiveness of the team. A number of team level activities had gone into the project. The leader was excellent in getting stakeholders' attention into project execution. Each and every phase, the team involved the respective stakeholders and senior management team. Team systematically followed the DMAIC steps. The project leader was supportive, and his problem-solving style encouraged team members to engage in problem-solving through DMAIC, even though team's problem-solving skills was not adequate at the beginning of the project. The project leader was effective in getting his team's active participation, in helping them acquire the necessary knowledge about the problem, and in gathering knowledge and synthesizing to get team level knowledge.

The project had clear and well defined, and stretched goal, and the team followed a systematic approach to executing the project. The project was important to the management as it was strategically important. The project attracted the involvement of Six Sigma deployment champion to closely follow the project progress. The project team did not have enough data on areas such as vibration analysis (sea transport), and hence the team had to depend on various processes such as observation and measurement of the process, understanding the process and use that knowledge to improve the process, and trying new things through trial and error method. Though the skill level of the team was not sufficient enough at the start of the project, during the course of the project, the team could acquire the necessary skills, primarily due to the motivation by challenging goals and project leader's style of functioning.

Due to team leader's motivational style, each one of the team members could engage in discussions to find a suitable solution. The team used to ask a lot of questions to clarify things and get a collective knowledge about the problem. As the deployment champion was personally involved in the project, team members put their efforts to carry out the project successfully. They had frequent meetings with the operational people and heard a number of narratives and stories that helped understand the process better. The team acquired working knowledge of various special tools such as Failure Mode and Effect Analysis (FMEA), Quality Function

Deployment (QFD), and new knowledge about the process such as sea-transport requirement, international marine logistics regulations, packing and other transport legal issues. All these learning practices helped team to arrive finally at possible factors to be considered, interfaces that need to be taken care of, and eventually could generate an implementable solution that led to cost savings. While finalizing the solution for implementation, the team used extensive feedback from stakeholders (the customer and gear box manufacturer). The team performed extraordinarily well as was evident from the solution that was novel and cost savings it registered. Although the project was delayed by more than two months from the original plan of 6 months, the financial savings achieved was higher than the anticipated gain.

8.4.4.3 Comparison with the conceptual framework

As shown in Table 8.5, *team's skill level, and complexity* have emerged as new emerging factors, which are found to impact learning in this case project. Some of the members lacked skills in problem solving, and the leader saw to it that nobody questioned their shortcomings. The problem's complexity coupled with the leader's encouragement made team members to learn and solve problems. In this process, team members enhanced their problem-solving skills. The stretched goal also contributed to the motivation for learning various aspects of the problem and acquiring additional knowledge related to the problem and succeed in the project as evidenced by the data analysis.

Table 8.5 Comparison of findings against the conceptual framework: Case 4 MFG2-1

Factors from case data (1)	Factors from the conceptual framework (from Literature review) (2)											Learning behaviours	Emerging them (4)
	Organizational level factors (2a)					Project level factors (2b)							
	Culture	Role structure	IT support	Use of metrics/data	Training	Project Leader	Method	Goal	Cross-functional team	Psychological safety	Team work		
Senior management involvement and support		√	√		√							KW	
Skills of the team not adequate												KW/KH	√
Clear and stretched goal								√				KW/KH	
Members from different functions									√			KW/KH	
Project Complexity													√
Leader supports in problem solving		√				√						KW/KH	
Data availability (not enough)				√								KW/KH	
Systematically executed the project					√		√					KW/KH	
Practicing tools and techniques	√		√	√			√					KW	
Skills were not questioned	√									√	√	KW/KH	
Each one involved in discussions without any fear	√									√	√	KW/KH	
Open discussion in the team	√									√		KW/KH	

8.4.4.4 Key findings and summary of the case 4

Context and antecedents:

Management involvement and support
Skills of the team (Team characteristics)
Clear, well-defined and stretched goal
Members from diverse functions
Complex problem
Project leader’s support in problem solving
Data availability
Method adherence
Tools and techniques
Skills were not questioned
Each one involved in discussions
Open debate in the team

Learning behaviours:

Knowing-what: Learning from outside experts
Learning from operating people
Feedback from customers
Reflection
Clarification

Knowing-how: Getting Insights into the problem
Discussions
Observation
Action
Discussions and idea generation
Learning by doing

Results:

Generated solutions with improved combination of variables
A novel solution identified and implemented

Emerging themes and factors

Two new themes emerged: Team characteristics in terms of skills level and project complexity. The skill level of the team was not adequate, and project goal was challenging. Due to the leader's style of functioning in supporting members coupled with a challenging goal, team members started learning tools and techniques. This helped enhance team members' problem-solving ability. In addition, the leader's behaviour created a somewhat conducive environment that helped team members feel psychologically safe and engage in knowledge exchange and team learning.

8.4.5 Case 5 analysis

Case 5: MFG2-2

Problem: This project relates to the field performance improvement in wind turbine farms. Wind turbine stops due to unwanted alarm (3 types of alarm) from the system, and the downtime due to these particular defects in a single turbine model caused a loss of 5600 hrs of electricity non-generation from 432 turbines in a year (in one specific turbine type). Each hour of downtime resulted in a loss of about 46,000 euro. The project involves wind turbines erected across the globe and had both complexity and uncertainty.

- *Project goal*: Reduction of the unwanted alarm by 80%
- *Project leader*: Experienced Black Belt
- *Project team*: 9 members (Maintenance engineer, service manager, software system specialist, Technical manager, field diagnostic administrator, representative from four business units)
- *Project duration: 7* months
- *The Performance achieved:* Solutions reached and implemented in new turbines, and implementation started on all existing turbines.

8.4.5.1 Causal network map

Figure 8.13 shows the causal network map for the case MFG2-2. Boxes are drawn with the respective concepts or factors such as context/antecedents, actions, learning practices and results. Arrows are drawn as explained earlier. The following section will explain through a narrative.

8.4.5.1 Causal network map: case 5: MFG 2-2

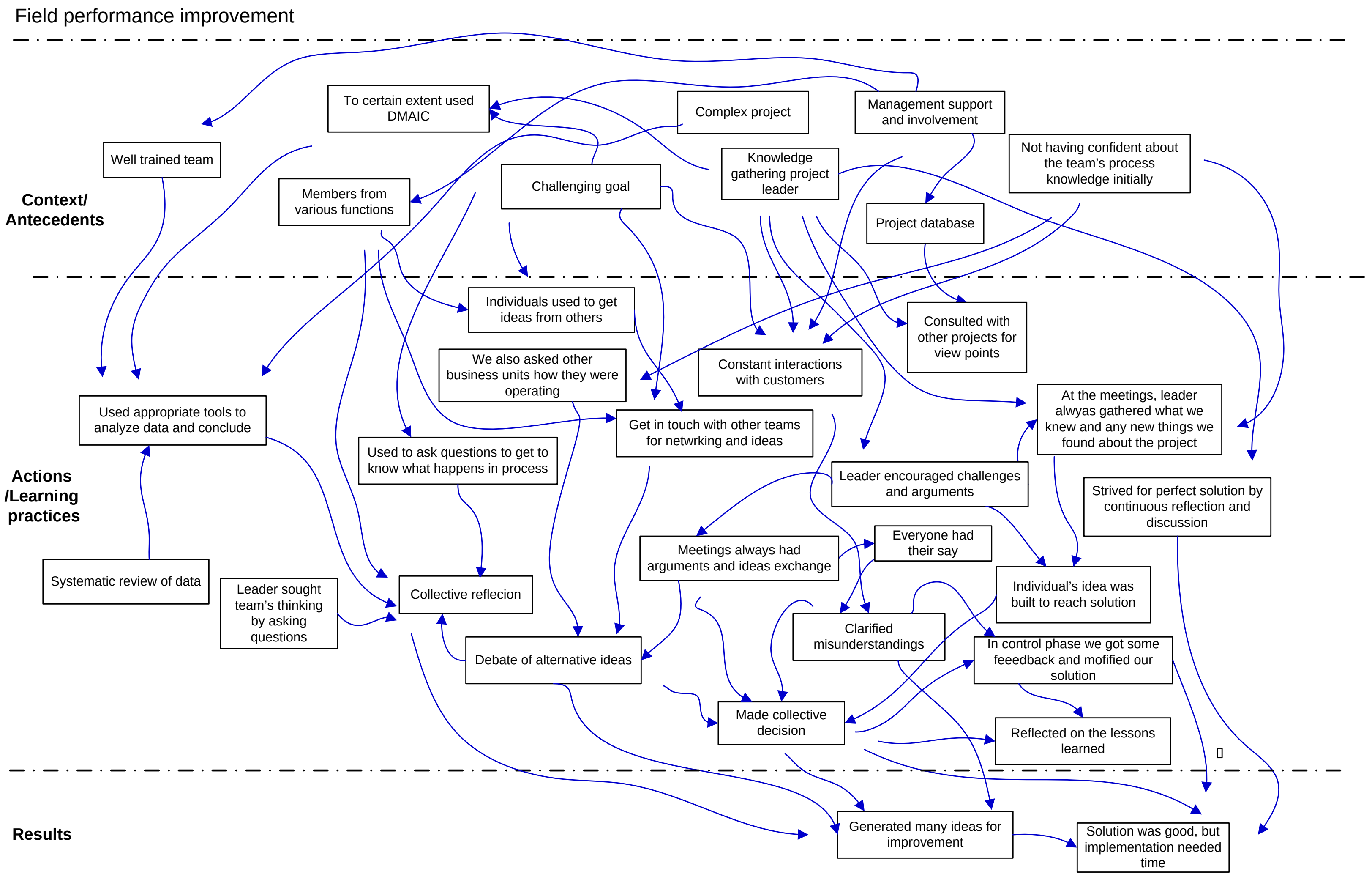


Figure 8.13 Causal network map: case 5: MFG 2-2

8.4.5.2 Narratives

Project team members are from various functions and were well trained in Six Sigma methods and tools. This helped them to analyze data systematically and follow the DMAIC method in approaching to solve the problem. The Project goal was challenging. The Project leader was found to be systematically gathering individual knowledge to get team level knowledge.

The project was complex in terms of geographic spread, the number of business units and wind farms involved and the number of variables affecting the problem. Variables that impact the failure alarm are wind speed, hydraulic pressure, voltage, wind speed, a reference position set in the software. Four measurement system analyses (MSA) for these four different measurements were required. Data had to be collected from sample wind farms across the globe. The team reported that they were in difficulties during the initial phase of the project execution in identifying various interfaces and their relationships, how to coordinate activities across the globe, and how to collect data and conduct trials at various places, or how to select samples for the study and trials. Only during the later part of the project could they finalize the variables to be studied, the regions and business units to be focused, and the approach to be followed. Four failure modes were to be investigated. A lot of experiments had to be carried out while implementing solutions. During the recommendation and implementation stages, the team faced problems on how to go about implementing a new software installation on all the existing turbines around the globe, which made the project closure uncertain.

The project team was well trained in Six Sigma method and tools, and were assigned distinct roles in executing the project. The team was found to have consulted Six Sigma database to get possible approach from similar projects. The uncertain situation found in the early phase of the project made team members to go out of the way to get more information by whatever means possible by each to get full knowledge of the process being investigated. This led them to consult other business units to know how various service tasks were being carried out. Team extensively consulted other running projects and established network with them to learn things from them. At each meeting, the leader used to gather team’s update on the new information and knowledge about the process in order to build a coherent understanding of the process, interfaces, problems, etc. Thus, it seems that uncertainty and complexity have incited the team for increased learning in the team.

Team activities included data analysis using tools, asking questions, arguments and ideas exchange, challenging, reflection and clarifying misunderstanding. Team leaders used to ask questions; encouraging debate of alternative ideas and promoting collective decisions. Individual's ideas were put into formulating solutions. The result was an optimal solution that was implemented.

8.4.5.3 Comparison with the conceptual framework

Table 8.6 summarizes the findings of case 5 that compares the findings with the conceptual framework. Two new factors that emerged from this case that are influencing learning are *project complexity and uncertainty*.

Table 8.6 Comparison of findings against the conceptual framework: Case 5 MFG2-2

Factors from case data (1)	Factors from the conceptual framework (from Literature review) (2)											Learning behaviours	Emerging themes (4)
	Organizational level factors (2a)					Project level factors (2b)							
	Culture	Role structure	IT support	Use of metrics/data	Training	Project Leader	Method	Goal	Cross-functional team	Psychological safety	Team work		
Senior management involvement and support		√	√		√							KW	
Well-trained team					√							KW/KH	
Members from various functions									√			KW/KH	
Challenging Goal								√				KW/KH	
A complex problem												KW/KH	√
Knowledge gathering leader		√				√						KW/KH	
Project database			√									KW	
Method				√			√					KW/KH	
Everyone had their say	√									√		KW/KH	
Clarified misunderstanding										√		KW/KH	
Leader encouraged challenges and arguments	√					√				√		KW/KH	
Data analysis	√			√			√					KW	
Collective reflections	√										√	KW/KH	
No confidence on the process knowledge initially												KW/KH	√

8.4.5.4 Key findings and summary of the case 5

Context and antecedents:

Management support and involvement
Members drawn from various functions
A challenging goal
Project complexity
Knowledge gathering leader
Project database
Moderate use of Method
Everyone had a say, clarified misunderstanding
Leader’s encouragement
Data analysis
Collective reflection
Project uncertainty

Learning behaviours:

Knowing-what: Learning from operating people
Learning from other projects
Learning from customers
Learning from outside people
Reflection
Clarification

Knowing-how:

Getting insights into the problem
Discussion and idea generation
Action
Learning from within the team
Learning by doing
Observation

Results:

The solution was right, but implementation needed time
The solution has solved the major problems faced by the customers

Emerging themes and factors

New emerging concepts: Project uncertainty and complexity

8.5 Cross-case analysis

Learning practices found from each case project was mapped and compared against the conceptual framework earlier in this chapter. Now it is time to look for any underlying similarities and associations among the case findings to form more general explanations and to examine the learning behaviours in the five case projects in their respective contexts. This will be done through cross-case analysis. As discussed earlier, our intention was not to find out the frequencies of each practice, but rather to identify all learning practices found in project teams and their relationships with managerial factors. Thus, the first purpose of the cross-case analysis is to identify all learning practices exhibited in the five sample projects that will answer RQ1. The second purpose is to determine all contexts and antecedents for these learning behaviours and performance consequences that answer RQ2 and RQ3.

8.5.1 Answers to RQ1

Totally 91 summary statements relating to learning practices are identified from the transcripts from the five case projects. They are coded into knowing-what (KW), and knowing-how (KH) learning behaviours as conceptualized and empirically validated in Chapter 6. Table 8.7 shows the learning practices, coding and the corresponding behaviours from the sample case projects. Both the learning behaviours (knowing-what and knowing-how) are observed in all the case projects. Thus, these findings answer RQ1 and are consistent with the earlier survey research findings in chapter 6.

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Table 8.7 Learning practices from the cases and coding

Case	S.No	Learning practices	Codes	Learning behaviour
MFG1-1	1	Accessed the database	(1) Learning from other projects	KW
	2	Learning about old projects	(1) Learning from other projects	KW
	3	Frequent meet with the customers	(2) Learning from customers/operating people (4) Feedback from stakeholders/customer	KW KW
	4	Consulted outside experts	(3) Learning from outside experts	KW
	5	Reflection	(5) Reflection	KW
	6	Clarified issues	(6) Clarification	KW
	7	Discussions	(8) Discussions and idea generation	KH
	8	Learning from each other	(7) Learning from within the team	KH
	9	Spent time at work area	(9) Observation	KH
	10	Experimentation	(10) Action (11) Learning by doing	KH KH
	11	Analyzed data using tools	(10) Action (11) Learning by doing	KH KH
	12	Discussing possible approach	(8) Discussions and idea generation	KW
	13	Frequent brainstorming	(8) Discussions and idea generation	KH
	14	Learned new tools and techniques	(11) Learning by doing	KH
	15	Discussed with customers about the results	(5) Reflection	KW
	16	Learning about interfaces	(12) Getting insights into the problem	KH

MFG1-2	17	Systematic project review and action	(5) Reflection (10) Action	KW/KH
	18	Briefing	(6) Clarification	KW
	19	Meeting	(8) Discussions and idea generation	KH
	20	Discussions	(8) Discussions and idea generation	KH
	21	Idea generation	(8) Discussions and idea generation	KH
	22	Understanding process dynamics	(12) Getting insights into the problem	KH
	23	Involvement of all stakeholders	(2) Learning from customers/operating people	KW
	24	Talked to other project people	(1) Learning from other projects	KW
	25	Involve process owners while arriving at solutions	(8) Discussions and idea generation (4) Feedback from stakeholders/customer	KH KW
	26	Discussions with process people	(2) Learning from customers/operating people	KW
	27	Interacted with other project teams	(1) Learning from other projects	KW
	28	Debate on alternative ideas	(8) Discussions and idea generation (7) Learning from within the team	KH KH
	29	Challenging in meetings on decisions	(6) Clarification (5) Reflection	KW KW
	30	Taking all viewpoints on solutions	(4) Feedback from stakeholders/customer	KW
	31	Innovative ideas	(8) Discussions and idea generation	KH
	32	Brainstorming	(8) Discussions and idea generation	KH
	33	Frequent observation	(9) Observation	KH
	34	Frequent work spot visit	(9) Observation	KH
	35	Use of data and analysis	(11) Learning by doing (12) Getting insights into the problem	KH
	36	Used statistical tools	(11) Learning by doing	KH

MFG1-3	37	Consulted project Database	(1) Learning from other projects	KW
	38	Learned new tools through Six Sigma data base	(11) Learning by doing (10) Action	KH KH
	39	Discussed the progress	(5) Reflection	KW
	40	Sought ideas from others	(3) Learning from outside experts	KW
	41	Process sequence was identified	(12) Getting insights into the problem	KW
	42	Involved process people while discussing	(2) Learning from customers/operating people (4) Feedback from stakeholders/customer	KW KW
	43	Consulted project Database	(1) Learning from other projects	KW
	44	Use of skills in solving problems	(11) Learning by doing	KW
	45	Everyone engaged in brainstorming	(8) Discussions and idea generation	KH
	46	Had arguments	(8) Discussions and idea generation (5) Reflection	KH KW
	47	Workshop	(8) Discussions and idea generation (10) Action	KH KH
	48	Review	(5) Discussions and idea generation (4) Reflection	KH KW
	49	Idea generation	(8) Discussions and idea generation	KH
	50	Skills and knowledge of others	(7) Learning from within the team	KH
	51	Discuss the impact of the project solution	(8) Discussions and idea generation (5) Reflection	KH KW
	52	Learned new tools through Six Sigma data base	(11) Learning by doing	KH
	53	Questions raised for clarification	(6) Clarification	KW
	54	Verified various aspects of the solution	(11) Learning by doing (9) Observation	KH KH

MFG2-1	55	Basic tools to analyze problems	(10) Getting Insights into the problem	KH
	56	Open discussions within the team	(8) Discussions and idea generation (7) Learning from within the team	KH KH
	57	Each one was involved in discussions	(8) Discussions and idea generation	KH
	58	Practiced problem-solving tools	(11) Learning by doing	KW
	59	Informal meetings	(3) Learning from outside experts	KW
	60	Heard stories	(3) Learning from outside experts	KW
	61	Meetings with operational people	(2) Learning from operating people/customers	KW
	62	Asking questions	(5) Reflection (6) Clarification	KW KW
	63	Discussions with customers	(4) Feedback from stakeholders/customer (8) Discussions and idea generation	KW KH
	64	Good grasping of the problem	(12) Getting Insights into the problem	KH
	65	Observation of the problem	(9) Observation	KH
	66	Understood process steps	(12) Getting Insights into the problem	KH
	67	Use knowledge to design a new process	(12) Getting Insights into the problem (10) Action	KH KH
	68	Tried new things while trial	(10) Action (11) Learning by doing	KH KH
	69	Feedback from customers	(4) Feedback from stakeholders/customer	KW

MFG2-2	70	Used appropriate tools and techniques	(10) Action (11) Learning by doing	KH KH
	71	Systematic review of data	(10) Getting Insights into the problem	KH
	72	Leader sought team's thinking by asking questions	(5) Reflection (6) Clarification	KW KW
	73	Used tools to get full process knowledge	(12) Getting Insights into the problem (11) Learning by doing	KH KH
	74	Asked other business units how they operate	(2) Learning from operating people/customers (3) Learning from outside experts	KW KW
	75	Individuals get ideas from others	(7) Learning from within the team	KW
	76	Ask questions to get to know what happens in the process	(2) Learning from operating people/customers (12) Getting Insights into the problem	KW KH
	77	Collective reflection	(5) Reflection	KW
	78	Discuss various ideas	(8) Discussions and idea generation (7) Learning from within the team	KH KW
	79	Get in touch with other teams for networking and ideas	(1) Learning from other projects	KW
	80	We had arguments and ideas exchange	(8) Discussions and idea generation (7) Learning from within the team	KH KW
	81	Constant interactions with customers and process	(2) Learning from operating people/customers (9) Observation	KW KH

MFG2-2	82	Challenges and arguments	(5) Reflection (6) Clarification	KW KW
	83	Consulted with other projects for view points	(1) Learning from other projects	KW
	84	Documented the projects details and lessons learned	(1) Learning from other projects (5) Reflection	KW KW
	85	Leader gathered what we knew and new things we gained	(12) Getting Insights into the problem (5) Reflection	KH KW
	86	Continuous reflection and discussions	(5) Reflection (8) Discussions and idea generation	KH KH
	87	Everyone had their say	(6) Clarification	KW
	88	Clarified misunderstanding	(6) Clarification	KW
	89	Made collective discussions	(8) Discussions and idea generation	KH
	90	Individual ideas were built to reach solutions	(10) Action	KH
	91	We got feedback and modified the solutions based on feedback	(10) Action (4) Feedback from stakeholders/customer	KH KW

For each case, the respective practices and their association with the conceptualized knowing-what and knowing-how learning behaviours are displayed in Table 8.8. The table shows the comparison of the findings from the five case projects. A tick mark in any cell in the table indicates that the corresponding learning practice was observed in the case project appearing in the respective column. The entries in Table 8.8 reveal that the case project 4 did not use other projects for learning. But, the majority of the projects had these practices. It was confirmed that the case project 4 is a new type of project and hence no similar projects were available for consultation. All other learning practices are found in each case projects, indicating that all other learning practices were observed in all case projects.

Table 8.8 Cross case analysis to answer the RQ2

KW/ KH	Learning practices	Case1 MFG1-1	Case2 MFG1-2	Case3 MFG1-3	Case4 MFG2-1	Case 5 MFG2-2
KW	(1) Learning from other projects	√	√	√		√
KW	(2) Learning from operating people/customers	√	√	√	√	√
KW	(3) Learning from outside experts	√	√	√	√	√
KW	(4) Feedback from stakeholders/customers	√	√	√	√	√
KW	(5) Reflection	√	√	√	√	√
KW	(6) Clarification	√	√	√	√	√
KH	(7) Learning from within the team	√	√	√	√	√
KH	(8) Discussions and idea generation	√	√	√	√	√
KH	(9) Observation	√	√	√	√	√
KH	(10) Action	√	√	√	√	√
KH	(11) Learning by doing	√	√	√	√	√
KH	(12) Getting insights into the problem	√	√	√	√	√

8.5.2 Answers to RQ2 and RQ3

The researcher has set the second and third research questions based on the literature review in chapter 2: **RQ2:** ***How do the learning behaviours of project team impact project performance?*** In order to answer this research question, the researcher needs to identify the results of each case project as perceived by the respondents along with the learning behaviours revealed in case projects. The findings from the data analysis (maps, narratives, and effect matrix) are tabulated in Table 8.9, which shows various learning behaviours and performance outcomes. The results clearly support the findings in chapter 6, that learning behaviours impact project performance.

Table 8.9 Project outcome of the case projects

Case projects	Learning behaviours observed	Project outcome
MFG1-1	KW/KH	Cost savings achieved as planned Exceeded the project goal
MFG1-2	KW/KH	Improvement in cycle time of the process High impact solution
MFG1-3	KW/KH	Learned people oriented issues Process Optimized Guidelines and procedures changed
MFG2-1	KW/KH	Cost reduction achieved Novel solution
MFG2-2	KW/KH	The solution was good, but the implementation took time Solution solved the major problem faced by the customers

Answers to RQ3: ***How do managerial factors (organizational and project level factors) impact learning behaviours and in turn project performance?*** In order to answer this research question, the researcher needs to identify the results of each case project as perceived by the respondents along with the antecedents and learning behaviours revealed in case projects. Within-case and cross-case findings across the five cases are analyzed to identify the various antecedents and learning behaviours. The results of the data analysis (maps, narratives, and conclusions) are tabulated in

Table 8.10, which shows the antecedents, learning behaviours and the cases where they are evident. Column 2 displays all factors (antecedents) from the conceptual framework and column 1 displays their respective groupings (organizational and project level). Column 3 provides brief descriptions of the principal characteristics of each factor, and column 4 shows the corresponding behaviours. Column 5 contains the case numbers in which the factors were observed and evidenced from the data analysis. By combining the entries of table 8.9 and Table 8.10, it can be inferred that these antecedents impact project performance through learning behaviours.

The case data reveal that Psychological safety is found to impact knowing-how. The data analysis further shows that management support and involvement, project database and IT support impact learning behaviours. In chapter 6 (study 2a), a quantitative study looked at the effects of project resources on knowing-what and knowing-how. The factor ‘resources’ was conceptualized to include specialist for projects (role structure), management support and IT support available for projects. Thus, the qualitative data analysis supports the findings of the quantitative data as established earlier.

H2*: Knowing-what and knowing-how mediate the effect of resources on project performance.*

H3*: Knowing-how mediates the relationship between psychological safety and project performance.*

The narratives of cases also reveal that the adherence to all activities in DMAIC is primarily happening through the project leader, which is consistent with the hypotheses 4 and 5 established in chapter 6:

H4*: Project leader’s knowledge building behaviour partially mediates the relationship between structured method and knowing-what learning behaviour*

H5*: Project leader’s knowledge building behaviour partially mediates the relationship between structured method and knowing-how learning behaviour*

Further, the case stusy also shows that challenging goal impacts learning behaviours.

Table 8.10 Factors and their association with learning behaviours from case studies

Grouping (1)	Factors (2)	Description (3)	Learning behaviours (4)	Cases where evident (5)
Organizational factors	Management support and involvement	Senior management involvement in project reviews and supporting and involving in projects	KW	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
	IT support and Project database	A database containing all projects both current and past. The database includes a complete report of the projects, analysis, findings, recommendations of the project team, team members, and lessons learned. The database provides complete information about the project from the start to the closure. IT support includes data analysis software and communication support.	KW	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
	Training	Project leaders and some members are trained in Six Sigma methods and tools	KW and KH	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
	Data availability and analysis	Data available for the team and analysis	KW	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2.
	Continuous improvement Culture	Fact based decision making	KW and KH	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
		Challenge the status quo/raising question/arguments/ clarified issues		MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
		Employee involvement, everyone is encouraged to participate		MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
	Project uncertainty	The team may not have enough knowledge about various factors, interfaces and their interaction with the problem during the initial phase of the problem. The team has to do additional activities to get full knowledge to bring out the various facets of the problem	KW and KH	MFG1-3; MFG2-2.

Project level factors	Project team composition	Cross-functional team: Team consisting of members from various related functions	KW and KH	MFG1-1; MFG1-2; MFG1-3; MFG2.1; MFG2-2
		Well-trained team: Some or all members of the team are trained in Six Sigma methods and tools.		MFG1-1; MFG1-2; MFG1-3; MFG2-2; MFG2-2
		The skill level of the team in problem solving inadequate		MFG2-1
Project level factors	Teamwork	Involvement in team activities and learning	KW and KH	MFG1-1: MFG1-2; MFG1-3; MFG2-1; MFG2-2
	Project leader	Experienced in Six Sigma project execution	KW and KH	MFG1-1; MFG1-2; MFG2-1; MFG2-2
		Provided encouragement to members in problem solving		MFG1-1; MFG1-3; MFG2-2;
		Supported toward problem solving		MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
		Knowledge gathering behaviour		MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2;
	Project goal	Challenging	KW and KH	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
	Method	Following systematic method for project execution	KW and KH	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2
	Project complexity	The project involves a number of factors or department functions and their complex interactions	KW and KH	MFG1-2: MFG2-1; MFG2-1; MFG2-2
	Psychological safety	Members feel psychologically safe to engage in meetings and exchange knowledge if a conducive and comfortable team climate characterized by interpersonal trust and mutual respect. Team members will feel safe for interpersonal risk taking, and he will feel the team will not embarrass, reject, or punish him for speaking up.	KH	MFG1-1; MFG1-2; MFG1-3; MFG2-1; MFG2-2.

In addition, the table shows project complexity, project uncertainty, and skill level of the project team as additional factors affecting these learning behaviours in some of the case projects. They are treated as contextual factors as they are found only in some projects.

Apart from providing empirical support to the findings of chapter 6, this case study reveal some of the organizational factors such as *data availability, training, continuous improvement culture, team member involvement, and* project level factors such as *project goals, team composition, and teamwork* that are found to affect learning behaviours.

8.6 Observing interactions between qualitative and quantitative study

The findings in chapter 7 suggest that when the goal level is highly challenging, the team that has limited knowledge in method may try to acquire skills in order to achieve the project goal. The data analysis of the case project 4 (MFG2-1) supports the findings by showing that the team, in fact attained a high level of performance and acquired skills in problem solving. The interview data further indicate that the project leader had an influencing effect on this. Unfortunately, this was not hypothesized in the survey research. Further empirical research is required to investigate this complex relationship, which might throw more insights into he effect of leader on the 'challenging goal-skill development' relationship.

Qualitative findings also revealed the need for additional statistical examination of the quantitative data, which helped better understand these qualitative results. In the present study, the data analysis of case projects 2, 3, 4 and 5 showed that leader behaviour encouraged psychological safety in project teams. In order to check this aspect, a correlation analysis was carried out and the result indicated that leader behaviour and psychological safety are highly correlated (r =. 68, p <. 01). This is consistent with the existing team learning literature which posits that project leader influences team psychological safety (Edmondson, 1999). Similarly, interview data showed that challenging goal influenced learning behaviours and this qualitative findings prompted to perform a subsequent correlation analysis to check for the relationship between challenging goal and knowing-what (r =. 40, p <. 01), and knowing-how (r =. 63, p <. 01), which confirm the relationships. This interactive process of the two research methods informing each other of the sequential mixed methods design provides consistency between the study strands and helps achieve interpretive rigor of the research conclusions (Teddlie and Tashakkori, 2009).

8.7 Summary of chapter 8

Chapter 8 dealt with the analysis and findings of the vast amount of qualitative data from five case projects. The data was triangulated by collecting data from management, project level interviews, and records and document. The data analysis through within-case analysis was presented in the form of the map, narrative and summary and key findings. The analysis was followed by a cross-case analysis showing comparisons of the results. Throughout the data collection and analysis processes, the researcher ensured and executed appropriate tactics as planned (explained in Chapter 5 and displayed in Table 5.15) to achieve construct validity, internal validity, and reliability. These will be explained in chapter 9 in discussion sections.

The findings have shown that the two learning behaviours conceptualized and empirically validated in chapter 6 impacted project performances, and supported the findings of the survey research on the impact of four antecedents (resources, psychological safety, leader behaviour and method) on learning behaviours and performance. Thus, this multiple case study research supports the findings of the survey research in answering RQ1, RQ2, and RQ3. The study also shows other factors (that are in the conceptual framework) that are impacting on learning behaviours. Apart from this, the case study analysis identified three contextual factors that have emerged (project complexity, uncertainty and skill level of the team) which are found to be influencing the two learning behaviours.

Finally, as a part of the sequential ‘‘*Quantitative* → *Qualitative*’’ research design, this study carried out additional quantitative analyses by using survey research data to confirm some of the unexpected findings of the case studies. Thus, this study observes the interaction between qualitative and quantitative research strands to achieve interpretive rigor.

CHAPTER 9

DISCUSSION AND CONCLUSION

This chapter summarizes the contributions and implications of this thesis. The research objectives have been achieved by providing answers to research questions RQ1, RQ2, and RQ3 by studies 2 (chapter 6). The study 3 in Chapter 7 offered answers to RQ4. Study 1 provided a multilevel framework of Six Sigma. This chapter discusses the contributions from Study 1, 2 and 3 to theory and practice. The chapter critically assesses the quality of the research against the research quality criteria set in chapter 5 to demonstrate that this research is valid and reliable. The chapter concludes with the limitations of the research and the researcher's personal reflections, and his future research agenda.

9.1 Critical review of the Research questions

The main objective of the thesis is to theoretically and empirically contribute to the scientific knowledge of Six Sigma phenomenon. Building on the notion that Six Sigma deployment success depends on project–by-project focus and learning mediates the project performance, the research focused on the learning behaviours and the factors that influence project success through learning and knowledge creation. With these objectives in mind, the thesis was set to explain Six Sigma phenomenon in terms of learning behaviours of the team, and the antecedents and performance consequences. The research started with a broad research question: *How does learning take place in a Six Sigma team?* Then the researcher developed the following four specific research questions based on a systematic and a focused review of literature:

***RQ1**: What are the different learning behaviours or activities exhibited by the project team?*

***RQ2**: How do the learning behaviours of team impact project performance?*

***RQ3**: How do managerial factors (organizational and project level factors) impact learning behaviours and in turn project performance?*

RQ4: *How do social aspects of the project team (goal) and technical aspects of project execution (method) interact to impact project performance through knowledge creation?*

Answers to these questions extend and refine our existing knowledge and understanding of Six Sigma. The research approached these questions, from a process based view, by identifying the components of the process view of learning in Six Sigma: antecedents, learning behaviours and performance consequences. Toward this objective, the researcher conducted a systematic review on Six Sigma and performance and a focused review of Six Sigma and team learning literature, developed eight testable hypotheses, followed by a rigorous quantitative research and case study research.

Using a systematic review process (Tranfield et al., 2003), a literature review was conducted by the researcher, that led to a multilevel framework of Six Sigma linking management actions, project execution and performance (study 1). The framework pointed out the importance of projects in Six Sigma deployment and the mediating role of learning and knowledge creation in project teams for project success and hence Six Sigma implementation success. This multilevel research framework turns out to be a significant contribution to the theory and research in Six Sigma that comes out of this research.

Based on the reviews undertaken, two distinct learning behaviours, *Knowing-what* and *Knowing-how* were conceptualized that provides answers to RQ1. These two learning behaviours are conceptualized to be practiced by teams during the DMAIC cycle. Each one comprises a set of learning practices.

An explanatory sequential mixed methods research design (*Quantitative → Qualitative)* was used to answer RQ2, RQ3 and RQ4. Study 2 and 3 (quantitative study using survey research) followed by a multiple case study (qualitative research) was carried out to empirically investigate and provide answers to these reserahc questions. In study 2 (chapter 6), the impact of learning behaviours on performance was examined using data collected from 102 project teams from two organizations, and it was established that Knowing-what impacts project performance through knowing-how. The study also investigated the impact of resources provided to the project by the management (technical factor), team psychological safety (social factor), structured method and project leader (knowledge building behaviour) on these two learning behaviours and performance.

Study 3 (chapter 7) through a quantitative study using the data collected from 102 project teams provides answers to RQ4. This study examined the impact of social aspects of the project team and technical aspects of project execution (adherence of method such as DMAIC) on the knowledge created in teams and project performance. The case study research (chapter 8), through five case projects, supports the findings of the study 2. In addition, the case study research brought out some additional factors (both contextual and antecedents) that are found to be influencing learning behaviours and in turn project performance

The rest of this chapter discusses the contributions of the research followed by future research directions.

9.2 Contribution from Study1: Multilevel framework of Six Sigma

Chapter 2, through a systematic literature review, provided a theoretically grounded multi-dimensional and multi-level framework (Figure 2.3), connecting three meta constructs-managerial actions, project execution, and organizational performance. The research thus identifies Six Sigma as a multi-level phenomenon and suggests a unifying theory of Six Sigma linking organizational (macro) and project (micro) levels. The review also offers a measurement model (Table 2.7) consisting of all factors and constructs from the reviewed literature that may help researchers for empirical research to assess the precise nature of the relationship between various dimensions of Six Sigma strategy and business performance.

9.2.1 Theoretical implications and future research

The multilevel model combines both micro and macro levels and brings out the links between them. Future empirical studies can be pursued based on the proposed model across different industries and sectors in order to explore the relationships among various factors of the model. Studies could examine how the various factors influence performance and how the contextual factors identified in the model moderate the effects of performance outcomes. Multilevel research would be able to capture much of the nested complexity of real organizational life (Klein and Kozlowski 2000). Data from a single organization (micro-level study) or a single observation from each organization (macro-level study) may not be sufficient for a multi-level study (Klein et al. 1999). The research does not claim that conducting multi-level research is straightforward, as collecting data from multiple respondents across multiple project teams and organizations is no easy task for any researcher.

The micro perspective on Six Sigma, such as focusing on all processes and variables in managerial actions, project execution, and individuals, can answer existing questions as well as open up new ones (Johnson, Melin, and Whittington 2003). Scholars suggest the emerging activity-based view that links macro phenomena with micro explanations (Johnson, Melin, and Whittington 2003; Johnson and Huff 1997; Crossan and Apaydin 2010) as a theorizing concept that could link individual, firm, contextual, and process variables. This view focuses on the detailed processes and practices that constitute the day-to-day activities of organizational actors (micro-level) and that relate to the outcomes (macro) and feedback loop from the context and organizational variables back to the actors (Crossan and Apaydin 2010). By considering the micro into the macro, researchers can uncover plausible linkages to performance due to Six Sigma and provide a unifying theory on this concept.

By using a micro orientation, the RBV and institutional theory can offer more insights than those explained in the literature thus far (Gowen and Tallen 2005; Braunscheidel et al. 2011) as well as tangible guides to managerial action (Johnson, Melin, and Whittington 2003). For example, a study by Gowen and Tallen (2005) fails to explain how resources in the form of routines, assets, and processes are configured or reconfigured to provide sustainable competitive advantage. The RBV is a firm-level framework (Barney 1991) and Six Sigma is a firm-level strategy that helps organizations achieve competitive advantage and performance improvement by improving the efficiency and effectiveness of various business processes by exploiting firm-level resources. The RBV might provide a theoretical rationale for Six Sigma by answering why it should be considered to be a strategy for competitive advantage. It might thus be a promising perspective to investigate and demonstrate how configurations of assets and Six Sigma practices take shape and become valuable and generate superior performance. If the RBV also captures managerial actions, the people who perform these actions, how they create and amend practices, and how they influence and are influenced by Six Sigma practices, then it may provide more insights into the phenomenon (Johnson, Smith, and Codling 2000; Barley and Tolbert 1997). Investigating Six Sigma through the lens of the RBV is a promising area of research and this would help explain whether Six Sigma is solely an operational improvement methodology or a more strategic change initiative (McAdam, Hazlett, and Henderson 2005).

The majority of the empirical studies on CSFs has only looked into their rich description, but not what goes on in practice. Similarly, process theory-based research offers information about organizational decisions and the changes that result, but not on what action actors take and with what tools. These findings would help provide guidance to practitioners. The authors know that managers and project leaders are responsible for success and that many CSFs are vital for implementation success. However, they need to know how they make a difference. A greater understanding of managerial actions and project teams' actions through field research can throw more insights into this. Small sample size cases with an in-depth study followed by a larger survey research would thus provide a holistic view through a contextual understanding of the phenomenon.

Although the review suggests that many project-level factors affect project success, we have yet to identify their differential impacts on project success. Further, some of these factors may directly affect project performance while some may do so through other intermediate variables. In addition, some factors may even act as contextual factors that influence performance through their interaction with other factors. Empirical research can bring out these aspects, and the findings will have implications for both research and practice. While relationships between contextual factors and structural factors have been well studied when the organization is a unit of analysis, they have been much less investigated in the project context (Shenhar 2001). Indeed, several scholars have recommended a more contingent approach to the study of projects, which may help new insights emerge (Eisenhardt and Tabrizi 1995).

While the link between project complexity/uncertainty and project performance has been demonstrated in previous action research studies (Nair, Malhotra, and Ahire 2011), this has never been tested empirically. Future empirical research can investigate the impact of the project-level factors on knowledge creation and in turn on project success.

Scholars have borrowed a number of management theories from other research disciplines to explain Six Sigma. While these theories provide insights at a piecemeal level, they fail to provide comprehensive guidance for understanding the process of Six Sigma including its antecedents, processes, and consequences. The interaction of multiple theories relative to single theories, integration of managerial actions, and involvement of people in the organization (interconnecting social identity, social exchange, and social capital theory), along with external influences such as customers and environmental factors, may explain the Six Sigma phenomenon from a proper perspective.

Absorptive capacity is an interesting avenue for future research. Extending the research by Gutiérrez, Bustinza, and Barrales Molina (2012), future research may explore the effects of various factors on various dimensions of absorptive capacity (acquisition, assimilation, transformation, and exploitation), which might throw more light on its capability to enhance organizational learning (Cohen and Levinthal 1989; Zahra and George 2002).

The infrastructural elements of Six Sigma provide a context for continuous improvement and enable a learning culture and dynamic capability (Anand et al. 2009; Gowen and Tallon 2005). A promising research area could be the empirical extension of the earlier research of Anand et al. (2009) and Gowen and Tallen (2005) to explore this dynamic capability and investigate the impact of factors that influence capability in the Six Sigma context.

Unlike other projects such as new product development projects, Six Sigma project members work only part time, whereas project leaders work full time. Hence, the degree of project success greatly depends on the effectiveness of project leaders. As project success is mediated through learning and knowledge creation, leaders' knowledge-gathering skills are also expected to have a strong effect on project performance. It would be worthwhile to examine this aspect, which may provide valid and fruitful information to practicing managers about the skills requirements of project leaders.

9.2.2 Practical implications

Books advocating various elements of Six Sigma implementation patterns, narrating a series of case studies and showing tremendous financial savings abound. Many of these ‘how to’ books focus on managing Six Sigma deployment, but fail to provide information on business practices that support the effectiveness of implementation. The present research takes a holistic approach on Six Sigma and shows its multi-dimensional and multi-level perspectives indicating various elements that need to be taken care for practical implementation. The review provides some tangible principles that might guide those responsible for implementing Six Sigma in organizations. The model offers a host of management and project level factors which, if managed well may guarantee project success and hence deployment success. The model thus provides guidance to the practicing managers for successful implementation of Six Sigma.

The model indicates that leadership commitment and support are the starting points for implementation success. The model points to the manager that effective leadership that can provide support and involvement right from deployment to project execution will lead to successful implementation. The framework shows that Six Sigma implementation success depends on the success of improvement projects that the organization carries out. The research framework further shows that project success depends on various project level factors which are likely to be affected by many organizational factors. The framework, thus directs managers to take required measures that enhance the project performance. Even if the project level factors such as leader, team composition, resources, adherence to structured approach, and training given to the team are appropriate for project success, project success may not be guaranteed as it is quite likely that the organizational factors which affect them are not conducive tor project success. Therefore, managers should consider both the organizational and project level factors to be appropriate. The framework points out that a good set of organizational factors alone is not sufficient for project success, but along with it, project level factors also need to be conducive to success. Finally, the model specifies that project success is mediated by learning that takes place in the teams. The framework indicates to the managers that he or she should provide an environment that is conducive for active learning to take place to enhance project success.

9.3 Contributions from Study 2 -Learning behaviours and factors affecting them

The study 2 provide an interdisciplinary treatment of knowledge management in Six Sigma process improvement teams, and offers a research model demonstrating how Six Sigma process improvement teams promote deliberate organizational learning.

9.3.1 Theoretical Implications

This survey research offers a series of relationships among factors and explains how process improvement teams such as Six Sigma promote deliberate organizational learning through practice. It was posited that Six Sigma resources facilitate knowing-what, and team psychological safety present in the team facilitates social interactions, which, in turn, promote knowing-how. This study demonstrates that knowing-what enables knowing-how, which leads to better changes in work processes by identifying cause and effect relationships among variables. These learning behaviours jointly facilitate knowledge creation and enhance team performance. This study also establishes the empirical distinctions between the two learning behaviours. Further, hypotheses involving method and leader’s knowledge building behaviour also establish interesting results. The impact of a structured method on these two learning behaviours is mediated through leader’s behaviour. The findings confirm that resources, psychological safety, method and project leader are important factors for the success of projects. It is also revealed that their effects on project performance are mediated by distinct learning behaviours.

The finding that resources influence performance through learning processes provides empirical support to earlier research that theorized that resources were critical to performance (Cohen and Levinthal, 1990; Lawrence and Dyer, 1983). The mediating effect found in this study refines the common belief that resources in process improvement projects have a direct impact on project performance, by demonstrating that resources impact on performance indirectly through learning and knowledge creation.

Team psychological safety was found to influence knowing-how but not knowing-what. This result is consistent with the earlier finding of Choo et al. (2007) that psychological safety affects knowledge created and not learning behaviour. As the knowing-how scale captured knowledge creation, innovative solution creation and implementation, this study also extends Edmondson’s (1999) and Tucker et al.’s (2007) findings that interpersonal climate influences learning and change efforts.

Prior research has shown that psychological safety is influenced by leader behaviour and team composition (Edmondson, 1999). The findings thus point out to managers to provide proper team structure and an effective project leader to promote better team social interaction that will help enhance performance.

Further, the findings point out that by providing resources towards training and other infrastructure without providing suitable mechanisms for managing and maintaining knowledge transfer among team members will not result in the expected project success. This finding rejects the notion that investing in more resources for projects enhances project success rate.

This study contributes to both operations management and knowledge management literature by advancing research in team learning; it examines the effects of organizational and social antecedents in process improvement environments through Six Sigma perspective. By incorporating organizational behaviour in operations management contexts, this study responds to calls for multidisciplinary research (Boudreau et al., 2003; Linderman et al., 2006). The study builds on earlier theorizing of team learning that promotes organizational learning (Senge, 1990; Edmondson, 1999) and extends the findings to process improvement teams (Mukherjee et al., 1998; Choo et al., 2007). The findings provide an important complement to existing work on performance capabilities due to team learning such as producing new products (Sarin and McDermott, 2003), hospital improvement processes (Tucker et al., 2007; Pisano et al., 2001; Nembhard and Tucker, 2011) and process improvement in quality management (Choo et al., 2007).

The study offers empirical support to prior research in Six Sigma process improvement by Linderman et al. (2010) and Lloréns and Molina (2006). Linderman et al.’s (2010) research framework proposes that leadership establishes an organizational design and culture that provides a foundation for the improvement infrastructure; technical support and social support collectively lead to knowledge creation. The study empirically supports the view that technical (resources) and social (in terms of psychological safety) support result in knowledge creation. Quality management practices involve both core processes, focusing on tools and techniques, and infrastructure processes, focusing on how the improvement processes are practiced (Flynn et al., 1995). Infrastructure practices such as management support, commitment, and motivation can create an environment supportive of core practices. The existing quality management theory supports the notion that to produce better outcomes from quality management strategies both core and infrastructure practices are necessary. Though recent studies suggest infrastructure practices work through the core aspects to produce improvement (Flynn et al., 1995; Kaynak, 2003; Rahman and Bullock, 2005; Zu, 2009), others fail to support this view (Powell, 1995; Samson and Terziovski, 1999). The majority of research reports conflicting results on how these two practices affect performance (Sousa and Voss, 2002). The reason could be an insufficient understanding of the interplay between these two practices in determining performance and, more specifically, the mechanisms through which they affect performance. This study empirically clarifies the notion that technical and social practices influence the learning behaviour of people and promote knowledge creation in process improvement project teams jointly, which, in turn, enhances performance.

Lloréns and Molina (2006) propose that learning will have a positive effect on Six Sigma team performance, and our study empirically supports this view by confirming that learning behaviour in Six Sigma teams does indeed enhance team performance.

The research demonstrates that knowing-what enables knowing-how, which leads to better changes in work processes by identifying cause and effect relationships among variables. These mechanisms jointly facilitate knowledge creation and enhance team performance. This study also establishes the empirical distinctions between the two learning mechanisms. Future research in knowledge management in process improvement environments should take note of the distinction. The research model and the measures developed here are equally applicable to any project teams focusing on process improvement.

The finding that resources influence performance through learning processes provides empirical support to earlier research that theorized that resources were critical to performance (Cohen and Levinthal, 1990; Lawrence and Dyer, 1983). The mediation effect found in this study refines the common belief that resources in process improvement projects have a direct impact on project performance, by demonstrating that resources impact on performance indirectly through learning and knowledge creation. The study empirically supports the earlier research (Linderman et al., 2010) that resources are a factor that influence project performance through learning and knowledge creation.

Team psychological safety was found to influence knowing-how but not knowing-what. This result is consistent with the earlier finding of Choo et al. (2007) that psychological safety influences knowledge created and not learning behaviour. As the knowing-how scale captured knowledge creation, innovative solution creation and implementation, this study also extends Edmondson's (1999) and Tucker et al.'s (2007) findings that interpersonal climate influences learning and change efforts.

9.3.2 Practical Implications

Organizations deploy quality improvement programs such as Six Sigma with a hope that these programs enhance performance and outweigh the investment made. The challenge faced by the organizations in deploying these programs is to ensure that project team focus their efforts in enhancing the success rate of projects. The first result, regarding the relationship between learning in team and project performance, underscores the importance of learning behaviours and knowledge created in teams. Teams have to ensure that the knowledge possessed by the individuals are gathered, synthesized and a new knowledge is created and applied appropriately for improved performance (Arumugam et al., 2013; Anand et al., 2009).

The study points out that social supports in terms of team psychological safety and resources provided to the project team impact the knowledge creation in teams and performance. Managers, therefore, need to ensure a better team climate in addition to project resources that help knowledge sharing in teams.

The research findings also show that providing resources towards training and other infrastructure without providing suitable mechanisms for managing and maintaining knowledge transfer among team members may not lead to project success. This finding, thus, rejects the notion that investing in more resources for projects enhances project success. Management needs to ensure proper environment in the organization that is conducive for knowledge transfer. This may include providing support and freedom to the project teams to consult external expertise and effective specialist project leaders (Black Belts/Green Belts) who possess sufficient knowledge building skills. The specialist project leaders must not only be trained in the tools and techniques of Six Sigma, but should also possess expertise in practices for generating ideas and encouraging knowledge transfer among team members.

Although many organizational level studies have shown that management support impacts Six Sigma deployment, this study for the first time establishes that management support enhances project success through learning behaviour. This further underscores the importance of management support for project success at various stages of the project execution.

The study also notes that team psychological safety impacts knowing-how behaviour. Prior research has shown that psychological safety is influenced by leader behaviour and team composition (Edmondson, 1999). Managers, therefore, must provide proper team structure and an effective project leader to promote better team social interaction that will help to enhance performance.

The measurement scales also indicate that eternal learning, knowledge transfer from external expertise enhances project success. Managers, therefore, provide any required support to the team for the external consultations if a project needs such information.

Although the research does not explicitly focus on tacit knowledge transfer, the conceptualizations of the two learning behaviours include tacit knowledge. The scale items used in this study for learning behaviours include processes such as reflection, observation and discussions that facilitate the transfer of tacit knowledge. These processes specifically make team members observe processes under investigation and generate discussions leading to generation of further ideas in their improvement cycle. The finding points to Managers about the importance of imparting training on these techniques so that team can benefit.

The scale item for knowing-what has tacit knowledge indicating that tacit knowledge capturing is also required even during the early stages of the project (Define stage) to capture the real issues and help formulate the problem in its proper perspective. The results indicate to managers that team needs to pay special attention to capturing tacit knowledge of team members, right from the early stages of the project.

Tacit knowledge is mostly held by the skilled persons and the transfer of them will only happen through social interaction. Thus, it is important for project leaders to facilitate such social interactions among project-team members and people related to the process in order to enhance project success. This underscores the importance of the social skills of the project leader. Managers should note the importance of this skill in project leaders

The results further indicate that project leaders need to document their findings and lessons learned for future reference. It was also revealed by the case study data, where the successful project teams had access to the information on old projects. Managers to institute such documentation so that project details and lessons learned are documented for future reference.

9.4 Contributions from Study 3 –The impact of goal and method on project performance

9.4.1 Theoretical implications

In addressing several calls for research to explore the theoretical underpinnings of Six Sigma (Antony, 2004; Linderman et al., 2003; McAdam, Hazlett, & Henderson, 2004; Schroeder et al., 2008), this study has extended the goal-theoretic model of Six Sigma (Linderman et al., 2003). Linderman et al. (2003, 2006) reconciled the difference between quality management and goal theory by showing that the Six Sigma method and tools interact with goals to exert an impact on performance. This study increases the validity of their study. The study has extended the theoretical model of Linderman et al. (2003), who note that “improvement goals motivate teams to engage in intentional learning activities that create knowledge and make improvements” (pp. 193–194) by incorporating knowledge as a mediator in the goal–performance relationship. This research empirically supports this view and shows that challenging goals have a significant positive influence on performance through knowledge creation in process improvement teams. This study helps add new insights to the existing stock of knowledge on Six Sigma and provides a conceptual extension (Tsang & Kwan, 1999) and empirical support for the goal-theoretic model of Six Sigma.

The mediated moderation model provides a new way of investigating the effect of goals on the performance of Six Sigma improvement projects and suggests that the goal–performance relationship is more complex than previously recognized. This study provides interesting insights into the phenomenon by showing how the structured method (technical)–and challenging goals (social aspects) are related in interesting ways. The findings show that the adherence to the method is vital for converting knowledge into implementable solutions, but at the same time it has an adverse impact on the direct effect of goal on performance. The overall moderation effect, however, shows a positive effect, such that high adherence to the method shows higher performance across all levels of goal, which is consistent with prior research (Linderman et al., 2006), suggesting that the moderation effect should be seen in the light of combined mediation and moderation. By investigating the contingency impact of the method on the goal–knowledge–performance relationship, this study helps new insights emerge and advances our understanding of Six Sigma.

Panel D in Figure 7.2 shows that with challenging goals, the performance of teams exhibiting lower adherence to the method almost reaches that of those adhering strictly to it. This finding suggests that Six Sigma teams with low adherence to the method can enhance their level of performance to approximate that of teams faithful to the method when a highly challenging goal is set. This further signifies that to gain enhanced performance, we need to have either high fidelity to the method or challenging goals. Thus, it seems that goals and level of application of the method are able to compensate for one another to some degree. This is arguably the most important finding in that it is interesting and somewhat surprising and has implications for both theory and practice. The following explanation can be given. The teams that use the method faithfully may follow it with confidence as members are fully trained in it and have sufficient skills to implement. By adhering to the method and by applying various tools and techniques throughout the DMAIC phases, they create knowledge, solve problems and identify the optimal solution. On the other hand, a team lacking the necessary skills, which follows the method more loosely, may have to take additional precautions to avoid any mistakes in their approach in order to be successful. A challenging goal may cause this team to reflect on aspects of activities or tasks that go wrong during the project's lifecycle. It may also keep the team from rushing into any quick judgments and thereby omitting any relevant tasks, preventing them from committing mistakes. All these additional actions by the team contribute toward learning and hence knowledge creation in the team. In an extreme case, as Latham et al. (2008) argues, an extremely challenging goal may even prompt such as team to conduct an additional search for alternative solutions, leading to further learning. The goal in this case seems to cue the team to take a more cautious approach, leading to enhanced performance (Latham et al., 2008). Thus a team that uses only a low level of adherence to the method can reach a level of performance consistent with that of a team that follows the method faithfully if the team is given a highly challenging goal. However, in this study, teams with low adherence to the method that were assigned a low goal were found to perform poorly. This finding, together with the results for high fidelity to the method across all levels of goal and for lesser use of the method, but with challenging goals, further signifies that to gain enhanced performance, teams need to either to implement the method faithfully or have challenging goals.

The findings that teams motivated by challenging goals make use of the method to a lesser degree in attaining task performance (direct effect), but a higher level of adherence to the method for converting knowledge into subsequent implementation, suggest that the project team is found to alter its choices in order to gain a higher level of performance. This is consistent with the STS perspective, which explicitly recognizes the authority of teams to alter work methods to improve effectiveness (Emery & Thorsrud, 1976; Trist, 1978). Through a higher level of adherence to the method (employing tools and techniques and logically established implementable solutions) during the "implementation" phase and the subsequent "control" phase, teams seek involvement, cooperation and coordination from stakeholders such as those in management and others involved in the process. The results imply that Six Sigma provides the technical means to break down existing structural barriers between teams and different functions to enhance project effectiveness (second stage indirect effect). In contrast, by not adhering strictly to the method (direct effect), Six Sigma goals provide motivation that leads teams to cease engaging with both management and other stakeholders, thus adding structural barriers. This differential effect is evident from the results, suggesting that peak performance is possible only when both technical and social systems are optimized. This is in line with the STS perspective, which emphasizes joint optimization to enable improved performance. Thus, the need for the joint optimization of technical and social systems is illustrated in this study. Although Six Sigma is a new quality management paradigm, existing theories from relevant fields can be applied in explaining this phenomenon. Relevant theories can provide new perspectives and insights into Six Sigma and enhance our understanding. By invoking STS theory together with the goal theory perspective to examine Six Sigma, this study joins the stream of research on Six Sigma that uses theories from other disciplines to explain this approach (e.g. Braunscheidel, Hamister, Surech, & Star, 2011).

Exploratory learning is the search for new possibilities, discovery, novelty, and innovation, whereas exploitative learning concerns refinement, re-utilization, production and implementation of knowledge (March, 1991). The results suggest that the Six Sigma method helps translate new-found knowledge in teams into workable and implementable solutions, thus exploiting this knowledge; hence, it is found to have a strong orientation towards exploitative learning. The study has shown that challenging goals encourage novel ideas and innovative solutions and knowledge creation, relating to exploratory learning (McGrath, 2001). Thus, in project teams, goals and the method promote exploratory and exploitative learning respectively, showing that Six Sigma projects help manage a balance between explorative and exploitative learning (Levinthal & March, 1993) and contribute to internal innovation (Tushman & O'Reilly, 1996). Our findings therefore provide empirical support for prior research which has argued that exploration and exploitation are simultaneously possible in Six Sigma deployment, showing that social aspects encourage explorative learning and technical aspects of the project encourage exploitative learning (Choo et al., 2007a, 2007b). The Six Sigma method and challenging goals are thus two important aspects of Six Sigma projects. This study provides empirical support to the growing research stream that investigates how technical and social components of quality practices lead to learning and knowledge creation, which is a prime resource in gaining competitive advantage (Choo et al., 2007b).

Most empirical studies on goal-setting theory focus on individual goals (Kleingeld, van Mierlo, & Arends, 2011; Locke & Latham, 1990) and the majority of studies on group goals focus only on stable work teams or experimental classroom teams. Field studies of group goal-setting are a challenging endeavour and are very rare in the applied psychology research discipline (Kleingeld et al., 2011). The study, by focusing on Six Sigma project teams, advances research into group goals and thus contributes to the work motivation research discipline.

Latham and Locke (2007) note “goal and knowledge connects goal setting to the entire field of cognitive psychology. Research so far has only scratched the surface of the issue of how goals and knowledge affect one another, and work together to affect performance” (p. 297). By incorporating knowledge into our research model, this study provides an empirical contribution to this stream of research.

9.4.2 Practical implications

This research has some significant implications for managers. First, the findings suggest that the adherence to the method in projects has a positive overall reinforcement effect on goals. This signifies the need to provide proper training for project team members. Assigning highly challenging goals without giving guidance on ways to attain them often leads to stress, pressure and suboptimal performance. Second, our findings suggest that Six Sigma goals can offer a powerful and compelling alternative to the faithful implementation of the method. A recent literature review found that out of 417 research papers published from 1992 to 2008, 256 (more than 51%) are related to methods and tools (Aboelmaged, 2010). Although much consulting in Six Sigma has been on the use of the tools and method, not enough consideration has been given to the social benefits of setting challenging goals. As Ghoshal and Bartlett (1994) put it, “By developing stretch as a key element of the internal environment, managers can influence the aspiration levels of individuals engaged in all kinds of activities – from ongoing improvement of existing and relatively standardized tasks to the creation of new products and businesses” (p. 100). The findings point out the importance of setting challenging goals in Six Sigma projects. Finally, if managers have a team that is not well trained in the use of the method, they can set challenging goals and still achieve significant improvements. Organizations that are in the initial stages of Six Sigma deployment can enhance new teams' capabilities in carrying out projects and the success of Six Sigma deployment by setting highly challenging goals. The finding should be welcomed by firms that are interested in Six Sigma deployment.

9.5 Future research direction

In study 2, the researcher has considered only four antecedents, resources, team psychological safety, method, and project leader in the research models in this study. The conceptualization of resources included organizational factors such as role structure, training, management team's support in executing projects, project sponsor's support, database (IT) support provided by the management. The other management factors that appear in the conceptual model can be included in the future empirical investigation. The case study research has brought out additional contextual factors (complexity, uncertainty and skill level of project team), which must be verified by a broad cross-section of data through survey research which could be a potential research.

The findings that leader's knowledge building behaviors influence project performance is consistent with the prior research in new product development teams (Sarin and McDermott, 2003). Further research on the effects of the other leadership qualities such as team building, stakeholder liaison on project performance can advance further insights into the capabilities of the project leaders for enhanced project performance.

Process knowledge is more procedural than declarative, context-specific and embodied in actions and skills (Singley and Anderson, 1989) and hence both knowing-what and knowing-how include tacit dimensions. Though the measurement scales on learning include items that captured tacit dimensions, the study did not investigate the interplay between tacit and explicit knowledge (Anand et al., 2010; Linderman et al., 2004) and how they are affected by resources, psychological safety, method and leader behaviour which may be a potential area for future research. The study did not include any unsuccessful projects, the inclusion of which would have given us some insight into the effect of project failure on learning behaviours. This could be an interesting extension for future research. Another interesting area of research would be the impact of project types and project complexity on the two learning behaviours and performance.

Given the short duration of Six Sigma projects, the possibility that teams may be inclined to spend too much time on learning rather than focusing on task aspects is worthy of further investigation. It may be possible for teams to compromise performance by overemphasizing learning, particularly when they have been performing well (Bunderson & Sutcliffe, 2003; Levinthal & March, 1993). Given our findings, it would be worthwhile studying the factors that influence such a choice. Future research can consider other mediators that may advance our understanding of the mechanisms that explain the goal–performance relationship. For example, participation in setting goals and satisfaction may mediate this relationship (Latham & Locke, 2007). With reference to moderators, future research should aim to focus on team climate constructs, such as the team's ability, goal commitment, performance feedback, incentives and rewards, leadership styles, self-efficacy and cognitive ability, as these moderators are found to affect the goal–performance relationship in the literature. The goal-setting literature also shows that task complexity affects learning in teams and hence future research might focus on this factor.

The goal-setting research views a goal construct as multidimensional, consisting of goal specificity and goal difficulty. In this study, only the goal difficulty was considered in the measurement scale. Future research may consider goal specificity in addition to goal difficulty and investigate their individual effects on performance. STS theory describes how organizational outcomes arise based on how people interact through social and technical systems and how both these systems affect each other and are affected by the external environment (Pasmore et al., 1982). Project uncertainty is an important external contextual factor that influences the project outcome (Shenhar, 2001). Investigating the effect of uncertainty on knowledge and performance could be a vital aspect of future research. The finding that teams take decisions on the degree of adherence to the method in various phases of project execution suggests that Six Sigma facilitates team empowerment. Additional research is needed to investigate this aspect further so as to establish factors that may exert an impact on team empowerment in Six Sigma project teams.

9.6 Assessing the research quality

The previous sections have described the research contributions to both the theory and practice. It is also important to evaluate the quality of research critically in order to establish a high research standard. Research quality criteria for evaluating the research was discussed earlier in chapter 5. Certain criteria were set out in that chapter for assessing the quality of research derived from literature, and now it is time to evaluate this research against those criteria critically. Teddlie and Tashakkori (2009) argue that because mixed methods research involves collection and analysis of both quantitative and qualitative data, three sets of validity checks should be employed to assess the quality of the generated inferences: (a) evaluating the inferences made on the basis of quantitative data using quantitative standards, (b) evaluating the inferences made on the basis of qualitative data using qualitative standards, and (c) assessing the degree to which the meta-inferences made on the basis of these two sets of inferences are credible. The evaluation of the survey research is summarized in Table 9.1, the case research in Table 9.2 and Table 9.3, assessment of the sample selection for case research and meta inferences made on the basis of mixed methods research in Table 9.4. The overall contributions to theory practice are given in Table 9.5.

9.6.1 Survey research

In the survey research, construct validity, criterion validity, internal validity and reliability of all the measurement scales used were carried out as per the guidance, standards and past practices found in the extant literature. Various statistical tests were conducted to confirm the established rules and norms. All tests proved that the values are within the accepted levels. They are explained in Table 9.1.

- Measurement scales for new factors (learning behaviours and resources) were developed based on the extensive literature reviews
- All other measurement scales for other factors were adopted from the existing validated scales from the literature

- Scale items were discussed with academic experts and practitioners for their unidimensionlities
- Principal component analysis was carried out to check if any items loaded on more than one factor
- Convergent validity and divergent validity were examined

Table 9.1 Summary of research quality criteria in survey research (Nunnally, 1978; Flynn et al. 1994; Forza, 2002; Malhotra and Grover, 1998)

Research quality criteria		**How was this achieved in this research?**	**Where was achieved in this research?**
Construct validity	• An instrument is truly a comprehensive measure of the construct being measured. • The extent to which the items in the scale all measure the same concept and the scale does not contain items that represent aspects not included in the theoretical concept.	√√ • Unidimensionality: Principal components factor analysis was carried out to check whether any items loaded on more than a factor or concept and if so, the items were removed from the analysis • Confirmatory factor analysis was carried out to check for the convergence between measures of the same construct (convergent validity), and separation between measures of different constructs (discriminant validity). • The average variance extracted (AVE) for each construct were estimated for scales and were found to be more than 0.5 (convergence) and compared the average values for constructs with the square of the correlations between the same pair of constructs for discriminant validity (AVE for the constructs were more than the squared correlation).	Chapter 6 Chapter 7
Criterion validity	The extent to which the scales are related to external referents	√√ • Independent variables were found to have a correlation with dependent variables in both the studies 2a and 3	Chapter 6 & 7
Reliability	• Consistency of a measure of a concept • Only little variation over time in the results obtained •Respondents' score on any one indicator tends to be related to their score on the other indicators	√√ • Reliability was operationlized as internal consistency (Flynn et al., 1994): Degree of intercorrelation among the items that comprise a scale (Nunnally, 1978). • Cronbach's alpha values were calculated for each scale, and the all the values obtained were above 0.7 which is recommended. • Adopted or used existing validated instruments from literature for most of the study variables.	Chapter 6 & 7

Research quality criteria		How was this achieved in this research?	Where was achieved in this research?
Content validity	• Measures the extent to which the content of the items in a summated scale indeed measures the concept it intends to measure	√√ • Developed questionnaire based on an in-depth review of the literature • Incorporated the experts' comments • Conducted a field survey (pilot) and modified the questions if necessary	Chapter 5
External validity/ Generalizability	• Ability of the scales to consistently yield the same response	√√ • Adopted or used existing validated instruments from literature for most of the study variables. For developing the new scales, extensive literature review followed by various confirmation tests by experts, practitioners, and pilot tests were carried out	Chapter 5

√√: means YES this research quality criterion is achieved in this research

√: means TO SOME EXTENT this research quality criterion is achieved in this research

9.6.2 Case study research

Various steps were followed up during the design, data collection and analysis stages of the case study research to ensure quality of research as explained in Table 9.2. In this research, the researcher used multiple case studies because he aimed to understand behavioural and historical aspects of the project relating to learning practices rather than a snapshot. Hence, Table 9.3 summarizes how the research met the research quality criteria set for case study research as explained in Chapter 5. In addition, specific steps were followed up while selecting cases for the case study research and verified some of the results of the qualitative research with the data from the survey research to ensure the credibility of sequential research design (Table 9.4).

Table 9. 2 Summary of evaluation of research quality criteria: case study (Yin 2009; Easterby-Smith et al., 2012; Maxwell, 2005)

Research quality criteria	**Case study aim**	**Case study tactics**	**How was this achieved in the research?**	**Where in this research?**
Construct validity	Correct operational measures for the concepts being studied are in place	• Use multiple sources of evidence • Establish chain of evidence • Have key respondents review draft case report	√√ • Strongly grounded literature based conceptual framework enabled the researcher to achieve construct validity. • Multiple sources of data evidence, methodological triangulation, enfolding literature, establishing a chain of evidence, structured reporting and independent peer review • Leaders and members (respondents) of the sample projects reviewed the draft case reports (narrative and maps) and necessary changes were incorporated based on their feedback and reports.	Chapter 3 Chapter 5 &8
Internal validity	Research quality standard refers to setting up a causal relationship	• Do pattern matching. • Do explanation building. • Address rival explanation. • Use logic models.	√√ • Used explanation building, pattern matching, narrative and causal mappings to explain the causal relationship	Chapter 8
External validity/Generalizability	Concepts and constructs derived from the study to have relevance to other settings	• Use theory in Single-case study. • Use replication logic in multiple case study	√ • Replication logic was employed through five case studies. As the findings are context specific, the results may not be entirely generalisable.	Chapter 8

				• Multiple case studies used the same conceptual framework and pattern searching through replication logic. • Research findings were discussed in different academic forum, such as conferences with a wide range of academics (operations management & quality management) as well as international conferences (DSI, US; Euroma, UK; Lean Six Sigma conferences, Glasgow) and with colleagues at the University of Strathclyde for outer control.	Chapter 8
Reliability	Similar observations are reached by other observers. Data analysis and findings follow a clear process to avoid idiosyncrasy.	•Use case study protocol •Develop case study database •Verifiation of results (conference, feedback from colleagues, journal publication)	√√	• Early definition of research quality criteria, case study protocol, case study reports, cross-case analysis, pattern matching, coding and causal network analysis, enfolding literature and reviews by academic research colleagues who have knowledge in Six Sigma, on maps, case study conclusion reports and the interpretation of the researcher	Chapter 5 & 8
Data and research evidence	What counts for data in this research for an auditable and multi-sources research evidence	•Organizational data •Financial performance data •Reported perceptions (others and researcher's) •Transcripts, Field notes, Documents and Artefacts	√√	• Companies' Six Sigma documents, annual reports, publications, company reports, field notes, research diary, electronic recordings of interviews, observations, coding and causal network maps were used as source of evidence to build explanations.	Chapter 8

√√: means YES this research quality criterion is achieved in this research
√: means TO SOME EXTENT this research quality criterion is achieved in this research

Table 9.3 Process of theory building from Case Study Research (Eisenhardt, 1989)

Step	Activity	Reason		This research
Getting started	Definitions of research questions	Focuses efforts	√√	Research questions and literature based conceptual framework was developed
	Possibly a priori construct measures	Provides better grounding of construct measures		
		Retains theoretical flexibility		
	Neither theory nor hypotheses			
Selecting cases	Specified population	Constraints extraneous variation and sharpens external validity	√√	Five case projects were selected from two case organizations from two countries
	Theoretical, not random sampling	Focuses efforts on theoretically useful cases – i.e. those that replicate or extend theory by filling conceptual categories		
Crafting Instruments and protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence	√√	Case study protocol and coding used. Triangulation of data collection from multiple sources
	Qualitative and quantitative data combined	Synergistic view of the evidence		
	Multiple investigations	Fosters divergent perspectives and strengthens grounding		
Entering the field	Overlap data collection and analysis, including field notes	Speeds analyses and reveals helpful adjustments to data collection	√√	Data collection and analysis overlapped
	Flexible and opportunistic data collection methods	Allows researchers to take advantage of emergent themes and unique case features		
Analyzing data	Within-case analysis	Gain familiarity with data and preliminary theory generation	√√	Within-case analysis done using mapping, effect matrices, pattern searching
	Cross-case pattern search using divergent techniques	Forces researchers to look beyond initial impressions and see the evidence through multiple lenses		

Shapping hypotheses	Iterative tabulation of evidence for each construct	Sharpens construct definition, validity, and measurability		NA
	Replication, not sampling, logic across cases	Confirms extends and sharpens theory		
	Search evidence for 'why' behind relationships	Builds internal validity		
Enfolding literature	Comparison with conflicting literature	Builds internal validity, raises theoretical debate and sharpens construct definitions	√√	Comparison with literature and conceptual framework
	Comparison with similar literature	Sharpens generalizability and raises theoretical level		
Reaching closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small	√	Common pattern explored among cases. More cases may be required for theoretical saturation

√√: means YES this research quality criterion is achieved in this research
√: means TO SOME EXTENT this research quality criterion is achieved in this research

Table 9.4 Assessing the credibility of meta-inference from the mixed method research (Creswell and Plano Clark, 2011; Ivankova, 2014; Teddlie & Tashakkori, 2009)

Criteria	Tactics		How this was achieved in this research?
Selecting participants for qualitative follow up-Project selection	Case study samples from those that participated in the quantitative study (survey)		Projects (and respondents) were selected from those projects (and respondents) which have participated in the survey
	Typical, extreme and or unique cases	√√	Case projects consisted of projects having broad scope, typical projects, and coming from different areas such as, Manufacturing, administrative, field service, failure analysis, logistics and transportation,
	Wide project topics		
Elaborating on unexpected survey results	Select project with extreme scores on dependent variables (performance)		Three projects with excellent performance and 2 projects with typical performance were selected for the case study
	Project with inconsistent and extreme scores in independent variables	√√	Two projects have extended project duration and projects with less degree of adherence to Method
			Two case projects affected by unforeseen events and situations (uncertainty) were included in the case study
Observing interaction between quantitative and qualitative studies	Iterative process between quantitative and qualitative research informing each other for further analysis: From qualitative emergent findings, any additional quantitative analysis prompted or vice versa?	√	Projects selected for qualitative studies from the quantitative participants only. Case projects selected to represent wide variations in predictor and outcome variable values. Additional quantitative analysis done to verify qualitative results.

√√: means YES this research quality criterion is achieved in this research
√: means TO SOME EXTENT this research quality criterion is achieved in this research

It is also important to mention that the literature review and the conceptual framework developed prior to data collection also meet good quality management research requirements. The research started with a systematic review of Six Sigma literature following a rigorous review process and research synthesis. This was followed by a focused review of team learning literature. The researcher developed a conceptual framework via combining different views of the scholars. Thus the researcher followed Eisenhardt who suggests that “Sound empirical research begins with strong grounding in related literature, identifies a research gap, and proposes research questions that address the gap” (Eisenhardt et al., 2007: 26). From the conceptual framework, the researcher identified the research gap from which he developed a broad research question. Then the researcher proposed four specific research questions to investigate empirically. Both the research questions and the conceptual framework provided a robust guidance throughout the field work (survey research and case research) ensuring quality of research right from the start.

Carrying out a quality research process depends on appropriate research methodology and following research quality criteria. The researcher participated various international conferences (Decision Science Institute, USA; EuROMA, UK; and Lean Six Sigma conferences, Glasgow), Research methodology workshop (Cambridge university, UK), Doctoral consortium (DSI annual meeting, USA) and Journal publishing workshop (EuROMA, Italy) and used these opportunities to discuss his research methodology with experts and researchers in Operations Management discipline to get valuable input on his chosen research methodology. These inputs helped him shape his research approach. Prof Cipriano Forza (University of Padova, Italy) and Prof. Chris Voss (London Business School) during Research workshop (EuROMA, 2011), Prof. Kevin Linderman, Prof. Rachna Shah, and Prof. Anand Nair (Michigan State University) during the Doctoral Consortiums (DSI, USA, 2011 & 2012), and OM scholars during the Research Methodology workshop (Cambridge University, 2011) are some of the academics with whom the researcher interacted and received valuable inputs on research methodology that helped shape his research approach followed in the research.

9.6.3 Contributions

The researcher is expected to contribute to the theory/knowledge in terms of novelty of research and 'adding value' to what is already known in the literature. This research adopted a mixed methods approach to contribute to the advancement in methodology application within the Six Sigma research. The author had made a contribution to theory by answering the four research questions established at the outset of this research and developing a better understanding of how learning and knowledge creation take place and what are the factors that impact them and their performance consequences. This is a less explored research area in Six Sigma literature. The contributions to theory and practice are explained in Table 9.5.

Research findings were presented and discussed at various international conferences in Europe and USA, which provided valuable feedback and input that improved the research process and outcome. This helped the researcher ensure that the research is valid and approved by expert reviewers. Meeting the requirements of good quality research and getting comments, and approval from the lead academics helped the researcher achieve a good quality research.

The details of the publications are given in Appendix IV.

Table 9.5 Summary of evaluation of research: Contributions (Yin 2009; Easterby-Smith et al., 2012; Maxwell, 2005; Ates, 2008)

Research quality criteria	**Research aim**	**Research tactics**		**How was this achieved in the research?**
Contribution to the theory	What is the added value to what is known already in the literature? What is the theoretical basis? How the findings enfold literature?	• Confirmation of existing theories • Extension of the theory into new areas • Advances in methodology • Developments in the application of techniques • A proof • Disproving a null-hypothesis • Generation of hypothesis • Generation of grounded theory • Generations of insights • Theoretical reflection on practice	√√	• Identification and descriptions of two learning behaviours • Identification of various antecedents of learning behaviours and performance consequences. • Clarifying various contextual factors that impact learning behaviours. • Clarifying the link between managerial actions (macro) and team level actions (micro) and project performance through multi-level framework. • Theory extension on goal theory perspectives • Applicability of theories from other discipline to explain the phenomenon • Applied a robust methofology combining both regression and path analysis to test hypoptheses • Offered a series of research areas through a multi-level framework of Six Sigma • Overall, this research contributes to theory building by confirming existing theory, offering extension of theory, and providing more insights into Six Sigma phenomenon for both theory and practice.
Contribution to practice	Are research implications and conclusions acknowledging policy makers or practitioners to help them in decision making into business or social issues?	• Suggestions, implications, etc. • Models, frameworks, road maps, guidelines, workbooks • Normative practices	√√	• The research provides useful guidelines to practicing managers for successful deployment (factors that impact project performance) • Brought out some contextual factors that can impact project success • Provides a multi-level framework that offers suggestions to managers for their informed decision making • Showed the importance of setting challenging goals for enhanced performance even from the new inexperienced team

√√: means YES this research quality criterion is achieved in this research

√: means TO SOME EXTENT this research quality criterion is achieved in this research

9.7 Limitations of the research

Certain limitations inherent to the research design and implementation should be considered in the interpretation of the research conclusions and related methodological observations. Purposive sampling was used in the quantitative study phase, which limits the generalizability of the study findings. Extending the studies to other operational settings and other countries, and more cross-sectional sample can yield a more generalizable research finding. That being said, the conclusions of this research cannot be related to locations as such, as the concepts and measurements used in this study are general in nature and may not be biased to any country’s culture.

The majority of the measurement scales was adopted from the existing studies. However, ppotential limitations of the measurement scales for the learning behaviours need to be mentioned here. The conceptualization of the two learning behaviors includes both tacit and explicit knowledge. Nonaka's knowledge framework (1991, 1994) provides a rationale for the use of various practices to generate group level knowledge. Socialization, externalization, combination, and internalization (Nonaka, 1994) are the four practices in the framework to capture explicit and tacit knowledge of team members to create new knowledge. Although the four practices are not explicitly used in the scale items of the learning behaviours in this research (knowing-what and knowing-how), the scale items nevertheless include representations of these four practices and showing the processes of learning and knowledge conversion found in Six Sigma projects. The data show that the two learning behavior constructs have passed various statistical tests (content validity, construct validity). They are also reliably measured (Chronbach’s alpha: 0.79 and 0.81).

Recall bias on the part of some of the respondents may have slanted the results, as there was a time lag for those respondents who have completed the project earlier. Besides, some project leaders and members have completed more than one project, and their experience would affect the learning in teams. In order to overcome the effects of this, leader's experience has been controlled for in the analysis. To the extent possible, the researcher has taken all possible measures during data collection and analysis to overcome all these shortcomings

With respect to the case study research, the findings are based on five case studies which might be criticized to be insufficient to generalize the results. The multiple case studies, however, have given the researcher the opportunity to dig deeply into each one of them to get insights. Looking into cases in different contexts such as products, project focus, and team compositions provided him with variations in the data and enhanced the possibilities for cross-fertilization across cases and organizations. The case research also discovered robust and powerful context-specific insights and dimensions of Six Sigma projects. In each phase of the case research, the researcher analyzed the data objectively and tried to avoid putting on his own interpretations and validated the findings and conclusions drawn through rigorous discussion with peers and verifying with the respondents. The researcher firmly believes that the case projects have resulted in interesting and robust dimensions and insights into the dynamics of the learning behaviours and their antecedents and consequences.

Secondly, even though the coding, causal mapping and pattern searching exercises during data analysis is peer reviewed, the interpretations still remain subjective to the researcher. To the extent possible, he tried to overcome the subjectivity in his interpretations by designing a robust case study protocol, writing up objective case study reports, triangulating data from multiple sources such as interviews, company documents, archival records, observations, etc., using data analysis techniques such as causal maps, pattern matching within-case and cross-cases, and verifying the findings with academic experts who have extensive knowledge in Six Sigma and knowledge management, and the respondents from the case organizations, and finally discussing with academic experts in various international conferences.

Finally, the sequential mixed methods research design also provided a more robust approach by applying a systematic process for selecting participants for qualitative follow-up, elaborating on unexpected quantitative results, and observing the interaction between qualitative and quantitative study strands.

On a theoretical level, therefore, the results can be generalized beyond the context of the study. The researcher believes that his findings are objective mainly because he used survey research and case study method rigorously as much as possible, taking all steps as required during the course of the research in design, data collection, analysis and interpretations, aimed at ensuring the quality of the quantitative, qualitative and meta-inferences in a mixed methods research leading to a robust, credible and trustworthy research.

9.8 Research Conclusion

The previous sections dealt with contributions and limitations of the research**.** I will summarize the key learning points and research conclusions in this section. The research started with an emphasis that Six Sigma has become an operational strategy that finds wide applications across industry sectors. Having originated from practice, Six Sigma lacks theoretical explanation that is evident from the literature review done as a part of the research. By tracking the development of the body of research based on the literature from 2000 to 2014 and synthesizing various perspectives, the research developed a theoretically grounded multi-dimensional and multilevel framework that connects three meta-constructs, namely managerial actions, project execution, and organizational performance. The research thus identifies Six Sigma as a multilevel phenomenon and suggests a unifying theory of Six Sigma that links the organizational (macro) and project (micro) levels. The research, thus, offers a better theoretical understanding of the Six Sigma phenomenon. The research also suggests some potential theoretical perspectives to explore the logic behind Six Sigma.

It is also found that the success of Six Sigma implementation depends upon project-by-project focus, and the project success is mediated by learning and knowledge creation in teams. Although a few researchers have paid some attention to investigate learning in teams, we know very little about the theoretical mechanism underlie it. It was the aim of the research to bring further insights into Six Sigma phenomenon by investigating learning and knowledge creation in project teams, and to contribute to theory and knowledge, and offer implications for practitioners. Through theoretical conceptualization and empirical verification, the researcher has established two learning behaviour: Knowing-what and Knowing-how that are taking place during Define, Measure, Analyse, Improve and Control phases of DMAIC cycle.

By answering research questions RQ1, RQ2, RQ3 and RQ4 through studies 2, and 3, this thesis has provided an extension and refinement of what we currently know about learning in Six Sigma teams, antecedents and performance consequences. Based on the findings, the process-based model of learning in Six Sigma project teams is displayed in Figure 9.1.

By investigating the effect of four antecedents, (resources, team psychological safety, method and project leader) on learning behaviours in Six Sigma project teams, the present research empirically clarifies to the managers how these factors impact learning and knowledge creation in project teams and in turn project performance. Further, the research showed that technical support to the project team (resources) and social practices in the team (team psychological safety) jointly promote learning behaviours in project teams and turn impact project performance.

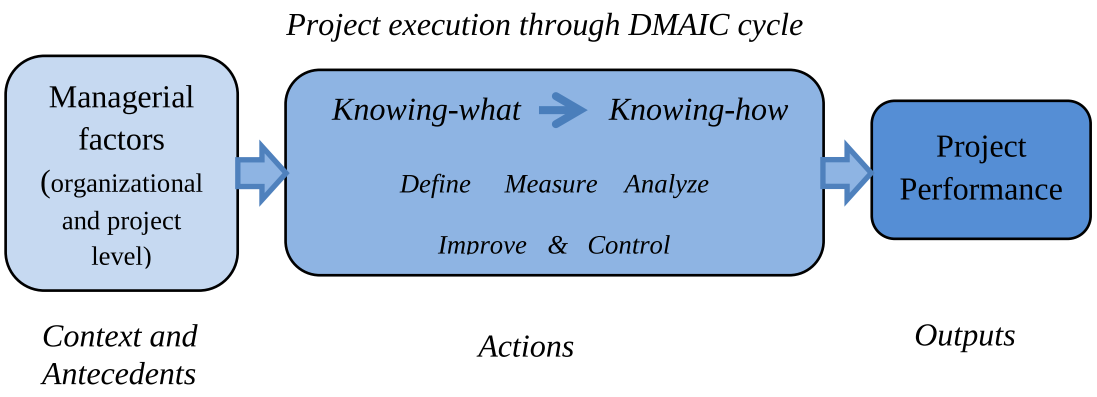

Figure 9.1 Process model of learning in Six Sigma projects

Through the lenses of Goal theory and Sociotechnical system theory, the researcher showed how the technical aspects of the project (structured method) and social aspects of project teams (motivated by challenge goals) jointly affect project performance. In addition, the research showed the importance of setting challenging goals in project teams for enhanced performance.

Finally, the research provides implications for practices and suggests new avenues for future research, which would take one to a higher level of understanding of the Six Sigma phenomenon.

9. 9 Some personal reflections and lessons learned

In this section, I explain my reflection.

Transferring and using process knowledge gained from projects to future projects

In Six Sigma project, project leader works full time, whereas members work only part time. Project team members working again in other projects are very remote as finding from the case evidence I gathered from the two sample organizations reveals. Leaders, however, lead a series of projects before they are moved to mainstream departments again. Hence the knowledge gained by the members during the course of a project execution, especially tacit knowledge may not be transferred to other parts of the organization, unless, they are engaged in projects in the future or they are consulted by future project teams. The majority of the process improvement projects document the process changes through standard operating procedures. Project teams also systematically document the project reports, presentations, and lessons learned in their database. Most of the sample projects of my survey data indeed have referred to the data base to see if any similar projects have been carried out in other parts of the organization for their learning. If organizations make it mandatory for each and every project team to consult the project database for possible knowledge, and subsequent interactions with the project teams, organizations may gain in terms of transferring knowledge from one project to another and thus institutionalizing organizational learning. I have suggested this to the representatives of both the sample organizations, which they agreed to implement.

In the current research, I did not focus on the extent of the utilization of knowledge gained from previous projects by the members in the current project. Though it is implied that the team’s improved skills due to previous projects indeed help conducting the current project more efficiently, I did not investigate the impact of the process knowledge gained from previous projects explicitly. Therefore, we do not know if the acquired knowledge was used in the current project or not. The literature lacks research into how learning from the prior projects, travels through the organizations in the Six Sigma context. Future research probably might throw more insights into the learning and knowledge used in Six Sigma projects compared to other projects.

Six Sigma role structures in the case organizations

The present research focuses only on the learning aspects of the project team. Though this research does not focus on the nature of the deployment and their comparative studies, I just reflect and briefly discuss here some of the salient features I notice from the sample case organizations.

At the time of the survey, MFG1 had 54 MBB, 427 BB and about 2000 GB. Total number of projects completed in the year 2009 were 1100, and the cumulative savings registered was 168 m Euro. Projects are tracked, hard and soft savings are evaluated, savings for 12-month periods are estimated, financial controller signs of the project and the project is followed up through project dashboard. The Human Resources department involved in selecting candidates for BB, and the selection process is rigorous. Selection criteria for BB candidates include evidence of high performance, evidence of high potential, proven analytical skills, proven people skills and fluency in English language. The salary review takes place on the very first day of the BB training a candidate undergoes. All managers are required to complete GB training and project, though they are not required to conduct further projects, either as a leader or a member; this is only to get them sufficient skills and knowledge in Six Sigma methodology. Of the 427 BBs in MFG1, 193 were trained in DfSS.

MFG2 had 14MBB, 47BB, and 360 GB. In the year 2009, the company had registered a total of 320 projects completed. Projects in MFG2 are selected based on predefined criteria, including the economic benefits, which are estimated in terms of Net Present Value of the estimated cost benefits for the next three years, which is quite different from MFG1, where the payback period is one year only. Of the 14 MBBs, 5 were not responsible for any Six Sigma deployment tasks, but working for different functions. Having made some remarkable contributions to Six Sigma deployment and coaching in the previous years, they were moved to other regular departments. These MBBs, however, are engaged in coaching of BBs and GBs on a need basis. Four MBBs belonging to the Process Excellence department whose primary function is to carry out strategic projects, and sometimes they also involve in coaching BB and GB project teams. Unlike MFG1, MFG2 does not have any salary revision right from the start, but only at the end of the financial year. The annual salary regularization is based on his overall contribution to Six Sigma. HR does not involve in the selection of candidates either for BB or GB, which is in contrast to that in MFG1. The selection is solely by the respective department and based on the requirement (any BB project need to be done). Thus, I see different strategies and approaches the two organizations have followed in their Six Sigma role structure setup. This only indicates the general trend that there are no standards being followed by industries either in their deployment strategies or training and certifying specialists.

Project types chosen for this research (DMAIC and DfSS)

In this research, I have not considered Design for Six Sigma (DfSS) projects, which are used in projects involving the design of processes or products. The primary reason for this was that we did not have enough projects available at MFG2 at the time of the survey. I did not want to add more complexity to the research, considering the time available for the research. DfSS projects involve new products or new processes and hence they involve a certain level of innovation in their approach, and hence different learning behaviours from that of DMAIC projects. The literature lacks research on learning in DfSS projects. Investigation of learning in DfSS and comparing it with that of DMAIC might provide more insights into exploration and exploitation in Six Sigma organizations. Though my research revealed the presence of exploration and exploitation in the context of DMAIC projects, a comparative investigation of DfSS and DMAIC projects in sample organizations might have provided knowledge on how organizations enhance their capabilities in both the domains and how organizations allocate their resources for continuous and radical improvements. By comparing how learning takes place in these two types of projects, one can explore and examine how radical learning and incremental learning are practiced in Six Sigma organizations and what are the factors that impact these learnings. In addition, by examining how organizations deploy and allocate their resources to these types of projects, one can find how incremental and radical innovations evolve in Six Sigma organizations, and how the improvement of the existing capabilities and creating new capabilities are achieved. This is a potential area for future research, which I intend to pursue in the near future.

Research methods used in this research

This research *extends and helps refine* our understanding of Six Sigma by explaining the mechanism underlying the phenomenon and their antecedents and performance consequences. As my research questions and the investigation required are on a new phenomenon, I decided to use a mixed method approach. It was rational for me to use a mixed methods approach so that any new and refined theory is emerging which could be tested subsequently. Mixed method research minimizes the problems of using either qualitative or quantitative method as explained in the dissertation. I find that very few doctoral dissertations use mixed method approach in the UK, and the majority of the researchers uses qualitative research. I also found during my interactions at various conferences that the mixed method research is not popular among the Ph.D. students of the UK universities. Creating more awareness of the advantages of a mixed method research among research students may bring out changes in the minds of researchers and, I hope, the UK Universities make right moves in this direction.

Six Sigma and future research

Six Sigma has grown rapidly across industry sectors since the 1980s. Although originated from the practice, it enjoys widespread attention and popularity among academics. This is evident from the growing literature, including reviews and investigations on its theoretical underpinning, apart from the cause-and-effect study of its impact on business performance.

The most significant aspect of Six Sigma is that no other quality improvement initiatives encompasses all features of Six Sigma such as focus on customer requirements, quantitative basis for performance comparisons (common metrics such as DPMO and sigma level) across industry processes, project-by-project focus, decisions based on the data, use of appropriate tools and techniques, specially trained people to lead improvement projects, and evaluating the business impact of each project. The projects also enhance the capability of individuals who are involved in projects. I am of the view that Six Sigma indeed contributes to business improvement. It is wrong to emphasize, however, that Six Sigma is the only initiative that can enhance business performance, as made out to be by the most of the practitioners.

The application of Six Sigma, though started from manufacturing, has now reached service sectors such as healthcare, government, finance and banks, education, and tourism. This expansion helps explain why we witness growing attentions by both practitioners and academics. Areas where Six sigma has yet to find the application in the future are project-based organizations and event management, such as exhibitions, marriage, etc., And one of productions such as movie making or events.

Research has gone into various success factors of Six Sigma, and to a limited extent, of its impact on performance. I have made a beginning of using multiple theories instead of a single theory to explain the complex phenomenon of project execution. The project success was explained by combining goal theory of motivational research discipline and Sociotechnical systems theory of organizational development research discipline and knowledge management. I hope that the academic fraternity would come out with more such multiple theoretical perspectives to explore the logic behind Six Sigma, which can advance our understanding of Six Sigma.

Final remarks

During the research journey, I witnessed a number of ups and downs. My transition from a working practitioner to an academic researcher has been a difficult proposition. I learnt intricacies and nuances of academic research and learned some basics of academic research process which is evident from my academic achievements: The publication includes three papers in international journals and six international conference presentations. And three best paper awards out of the six conference papers.

In the course of my academic life, I had chances to meet and interact with many academic scholars both from Europe and USA. I had opportunities to discuss my research questions, approaches, and problems with them, and at times I used to get convincing suggestions and guidance which helped shape my approach to research. In addition, many journal papers I studied, have contributed to improving my research capability.

When I started my research, I thought I was going to make a big change in the science of Six Sigma and the way we understand Six Sigma. Realistically, I have made only a small dent in the body of knowledge in Six Sigma. The systematic literature review provided a multilevel framework of Six Sigma. It provides guidance to practitioners, advances a theoretical insight into the Six Sigma phenomenon and offers a series of research avenues. Second, my research explained the mechanism of how learning takes place in Six Sigma project teams, the relationships between managerial factors and the learning behaviours and how they impact project performance empirically. These findings help advance our understanding of the Six Sigma phenomenon and provide valid information to practitioners toward their informed decision-making process. Third, through a multi-disciplinary research using theoretical arguments and empirical analysis, I have provided a logical explanation for the ‘‘goal-knowledge-performance’’ relationship, and how a challenging goal and structured method are related in interesting ways, which offers valuable guidance for practicing managers and provides implication for research.

9.10 Future research: Action Research

Having investigated the impact of project level factors on learning and knowledge creation in project team in this research, I would like to explicitly investigate the important aspects of project contexts which have received very little research attention in Six Sigma literature. I propose to carry out further research to get more insights and build further theory on Six Sigma through action research. It is also worth investigating to identify any other contextual factors that may influence learning and project performance.

Action research fits within the qualitative research paradigm (Miles and Huberman, 1994). In action research, the investigator becomes part of the field of study. It has an explicit focus on action and promoting change within the organization. The researcher is involved in this action for change and subsequent application of the knowledge gained elsewhere. Action research is a methodology that links theory, research, and practice, advances new knowledge and understandings via iterative action cycles. For action research, generalization becomes identical to the extent to which the knowledge is brought to influence human practices. Action research can involve the collection of both quantitative and qualitative data.

Three common themes of action research are:

1. The focus of the research is the management of change (Cunningham, 1995)
2. Involvement of the researcher and in particular a close collaboration between project members and the researcher (Zuber-Skerritt, 1996)
3. The results should have implications beyond the immediate research project or research setting; results could inform other contexts and subsequent transfer of knowledge gained from one specific settings to another (Eden and Huxham, 1996)

Action research provides a useful methodology for theory development and validity of various research outputs (Eden and Huxham, 1996). Action research focuses simultaneously on a critical examination of the research process alongside a very practical concern for useful outcomes. The power of action research rests in its ability to take on complex systems and multifaceted problems without expecting simple answers, but with a commitment to honoring the knowledge and experience of others and working together to bring about positive change.

In view of the limited knowledge in the literature, the following research questions can be addressed through an action research.

1. What are the key contextual factors that impact learning and knowledge creation in project teams?
2. What is the relationship between context factors and project performance?
3. How do project context and project level factors together affect learning in project teams?

Though my research has identified project context variables, such as complexity, uncertainty and skill level of the project team that are found to influence learning behaviors, a clear conceptualization of these variables and how they on their own and in combination with other project level factors impact learning and knowledge creation are not clear. Action research through my own field investigation can bring out new insights.

The future action research study would take those factors which have emerged from the current research as starting points. Figure 9.2 shows the structure of the proposed action research study into the contextual factors and how they interact with other factors to impact learning and project performance.

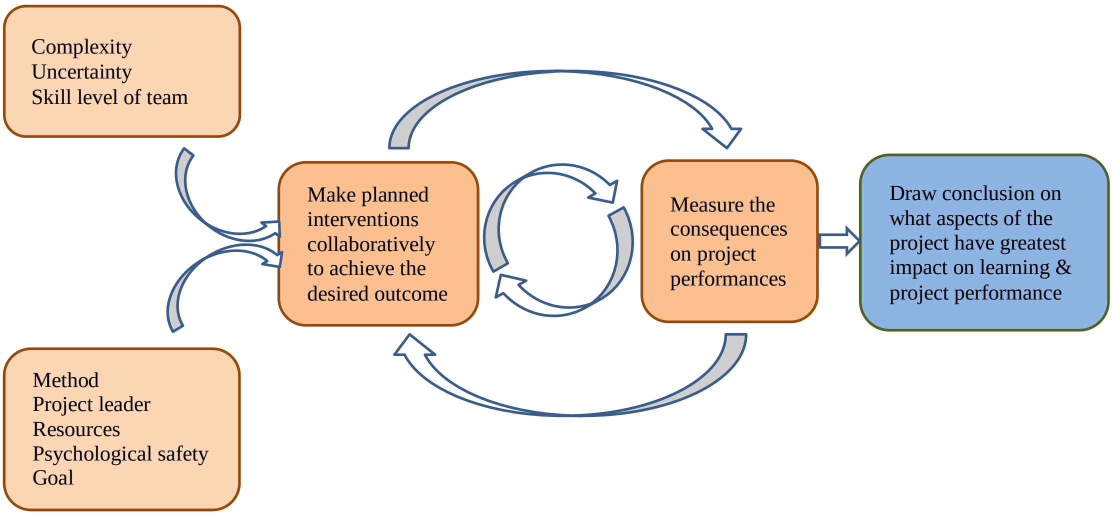

Figure 9.2 – Structure of proposed action research intervention study

Following are the steps recommended by Coughlan and Coghlan (2002).

1. Articulating an initial setting of the context and purpose.
2. Working with other members of the system as to what the data means ('shared diagnosis').
3. Deciding together what needs to be worked on in order to change the system in the desired direction.
4. Making planned interventions collaboratively in the system on the basis of the planned action to achieve those desired changes.

5. Evaluating both intended and unintended outcomes and reviewing to see what needs to be done next, and so repeating the cycle.

6. Standing back to reflect on steps 1 to 5, and reviewing what learning is taking place and what knowledge is being generated. Learning what works and does not work, and why (theory building).

By undertaking an intervention study, further in-depth theory could be developed surrounding the emerging themes from this study. I will involve myself in a set of projects as a facilitator-engage with several Six Sigma projects-in a participating organization. I will also involve in decision making, implementation, and the change process. Thus the project team (client) and I will actively be engaged in solving a client initiated project dealing with a certain business problems (Schein, 1987).

Eden and Huxham (1996: pp 84) have stated "doing action in action research demands experience and understanding of methods for consultancy and intervention." This means that the researcher needs to be aware of the nature of client-centered activity and how this differs from 'pure' research methodologies, and he needs to have a good working relationship with the client organization. Luckily, I have a good successful exposure and experience in consulting profession, having successfully implemented change initiatives in a number of organizations. It is also to be noted that I have developed good working relationships with the two organizations that have collaborated on the current research. Therefore, there is potential for action research to be carried out at one or both of these organizations.

The proposed action research may focus on the mechanisms of the contextual impact of the potential variables and the conditions governing their magnitude. Analysis of the systematically collected qualitative data through close engagement with the projects throughout the project execution will help understand the underlying patterns and relationships, and also will throw more insights into any other factors that may emerge. The insights gained from this action research will uniquely contribute to context-based theory-building.

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Appendix I

Survey questionnaire

Learning and Six Sigma project performance

By only those who were involved in Six Sigma Project (within the last 2 years) as a project leader or as a member.

1. Project name (short name):……………………… …………
2. Number of persons in the team:…………
3. Your responsibility in the project: (Please tick whichever is applicable):
    - Leader
    - Member
4. Process improvement objective or goals were (Please tick whichever is applicable):
    - Rejection/Rework
    - Variation reduction
    - Sigma level
    - Capability index (Cpk , Cp)
    - First Pass Yield % (FPY)
    - Others (please specify): …………..………………..

5. Project start date:… ..……………
6. Duration of the project (months):……………
7. Your skill level in Six Sigma: (Please tick whichever is applicable):
    - BB
    - GB
    - Others (please specify)……………
8. Number of years of experience:
    - Job Experience …………..
    - Project management experience………….
    - Six Sigma experience………………..

9. Nature of the project:
    - Operational

- Transactional
- Design for Six Sigma

10. Is it your first project?
    - Yes
    - No
11. If you have answered ‘No’ to question 9, please TICK the number of Six Sigma project you were involved so far.

    2 3 4 5 > 5

12. Number of members in the project team including the leader
13. Whether the project was completed within the scheduled time
    - Yes
    - No

If you have answered ‘No’, the project was extended by:

1 2 3 4 > 5 months

Note for the questions 14 to 21:

Please choose the appropriate number at the right of each item that best reflects the project you have mentioned in page 1 of this survey.

1= Strongly disagree, 2 = Disagree, 3 = Slightly disagree, 4= Neutral, 5= Slightly agree, 6= Agree, and 7= Strongly agree

14. Six Sigma goals

1. Project goals were clear and specific
2. We found it very difficult to achieve the project goals
3. The project goals were challenging to us
4. The goal was derived from the voice opf the customer

15. Six Sigma methodology

1. We followed strictly the sequence of DMAIC or similar methodology 2. Each step in DMAIC (or similar methodology) was faithfully completed
3. Regular project review was conducted during the project
4. The team frequently used Six Sigma tools to analyse data and information

16. Management Support

1. Senior management helped to remove any barriers in project execution
2. We have a hierarchy of expertise like MBB, BB, GB or equivalent
3. Our project sponsor was supportive throughout the project
4. We have systems/database where we documented our project details
5. Management team provided necessary support for project execution
6. Our Belt system was available for consultation

17. Project performance

1. We met or exceeded customers' expectations in this project
2. The cost savings or the strategic impact of the project were significant
3. The team had superb results on the project
4. The project was effective in improving the process

18. Knowledge created

1. The team generated many ideas while doing the projects
2. Doing this project enhanced the team's abilities and knowledge
3. The solutions found in this project were clearly unique and innovative to the company
4. We learned new tools and techniques of Six Sigma

19. Knowing-what

1. We collected information from Industry friends outside our team
2. We talked with customers and suppliers about our processes
3. We talked to the people having similar experience in Six Sigma projects to find out what has worked well

4. We reflected on our understanding of the process

20. Knowing-how

1. We carried out observations on the processes to understand it better
2. We had a number of group discussions to get new information and new ideas
3. We were able to specify the impact of causal variables on project outcome
4. Degree of change implemented was greater on process variables

21. Psychological safety

1. Members of the team were able to discuss problems and tough issues openly
2. Members of the team accepted each other's differences
3. No one from this team deliberately acted in a way that undermined my efforts
4. Working with members of this team, my unique skills and talents were valued and utilized

22. Project leader

1. Project leader provided constructive feedback
2. Project leader helped the team to focus toward the objective of the project
3. Project leader guided the team to select the optimal solution
4. Project leader initiated meetings to discuss team’s progress

Appendix II

Bootstrapping

Simulation research has shown that bootstrapping is one of the most powerful methods for testing mediating effects, and a growing literature recommends the use of bootstrapping for assessing indirect effects (Preacher and Hayes, 2008; MacKinnon et al., 2004; Williams and MacKinnon, 2008). In bootstrapping, the initial sample is conceptualized as a pseudo-population representing the population from which the sample was derived. By making use of numerous samples (usually 1,000 or 5,000 resamplings are recommended) drawn from the initial sample, the bootstrapping method estimates test statistics such as standard error and confidence interval for the sample. An empirical approximation of the sampling distribution of an indirect effect is built and used to estimate the confidence interval (CI) for the indirect effect. Using bootstrapping, no assumptions about the shape of the sampling distribution of the statistics (such as normality) are necessary while making any inferences (Stine, 1989).

Figure A1 shows a schematic representation of the double mediation effect of resources on performance by knowing-what and knowing-how. The figure shows the direct effect of resources on performance (path $c^{'}$) and the specific indirect effects of resources on performance via the two mediators. In the figure, a_1 refers to the (unstandardized) slope coefficient of knowing-what regressed on resources, a_2 refers to the slope coefficient of knowing-how regressed on resources, and a_3 refers to the slope coefficient of knowing-how regressed on knowing-what; b_1 and b_2 refer to the conditional coefficients of performance regressed on knowing-what and knowing-how respectively, when both are included as simultaneous predictors of project performance. The specific indirect effect of resources on performance through knowing-what is quantified as $(a_{1*}\, b_1)_,$ and the specific indirect effect of knowing-what and knowing-how is quantified as $(a_{1*}\, a_{3*}\, b_{2).}$

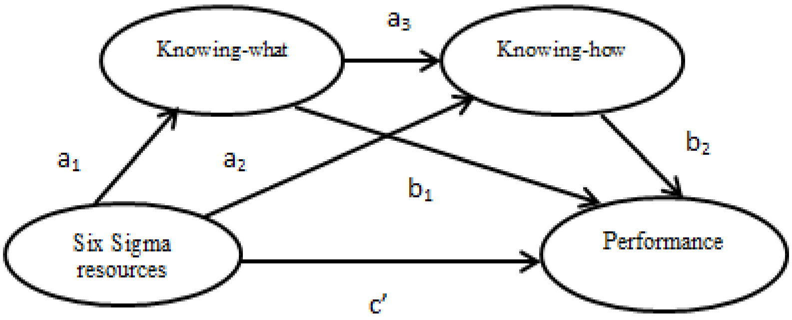

Figure A1. Multiple mediation model

Using regression analyses, regression coefficients ($a_{1,}$ a_2, $a_{3,}$ b_1 and b_2) are found. Then 1,000 bootstrapping estimates are found for these coefficients using SPSS syntax. Indirect effects through knowing-what (a_{1*} b_1) are calculated for these 1,000 resamplings. The distribution of these 1,000 estimates serves as empirical, non-parametric approximations of the sampling distributions of the indirect effect of knowing-what. An inference is made about the size of the indirect effect in the population by using these estimates to generate a CI% confidence interval. This is done by sorting the 1,000 values of the indirect effects from the low to the highest. In this ordered set, for a 95% confidence interval, for example, the lower bound of confidence interval is defined as the value of (a_{1*} $b_{1)}$ in the 1,000 (. 5-CI/200) th, which is the 25th position, and the upper bound is the value in the 1+1000 (. 5+CI/200) th, which is the 976th position. This procedure yields a *percentile* bootstrap confidence interval. The percentile bootstrap CI can be improved by calculating bias-corrected (BC) intervals, where the end points are adjusted to obtain a bias-corrected confidence interval (Efron, 1987; Stine, 1989). A similar procedure is used to estimate the CI for the indirect effects of knowing-what and knowing-how (a_{1*} a_{3*} b_2)$_.$ If zero is not found between the lower and upper bound, then the indirect effect is not zero with CI% confidence. That is rejecting the null hypothesis that the true indirect effect is zero at the 100-CI% level of significance.

Table A1. Mediation of the effect of resources on project performance through knowing-what and knowing-how

Mediator	Point estimate	S.E.	Bootstrapping			
			Percentile 99.5% CI		BC 99.5% CI	
			Lower	Upper	Lower	Upper
Knowing-what	0.094	0.063	-0.024	0.226	-0.005	0.214
Knowing-what and knowing-how	0.207	0.065	0.1254	0.386	0.084	0.267

S.E: Standard error; BC: Bias corrected; CI: Confidence interval; 1,000 Bootstrapping samples

Table A1 displays the bootstrapping output. Estimates for the specific indirect effects of knowing-what, $(a_{1*} b_1)$ =0.094, and those of knowing-what and knowing-how, $(a_{1*} a_{3*} b_2)$ = 0.207, are given along with the percentile CI and bias-corrected CI. From the table it is evident that the combined mediation through knowing-what and knowing-how is significant at $p < 0.005$.

Appendix III Case study protocol

Researcher: Arumugam Velaayudan

PhD RESEARCH PROJECT

University of Strathclyde, Glasgow

2011-2014

An overview and objective

The purpose of the research project is to identify various learning behaviours that are practiced by Six Sigma project teams, and factors that impact those behaviours and in turn project performance. The conceptual framework developed from the existing literature (Six Sigma and team learning literature) will guide this empirical investigation (Figure A2).

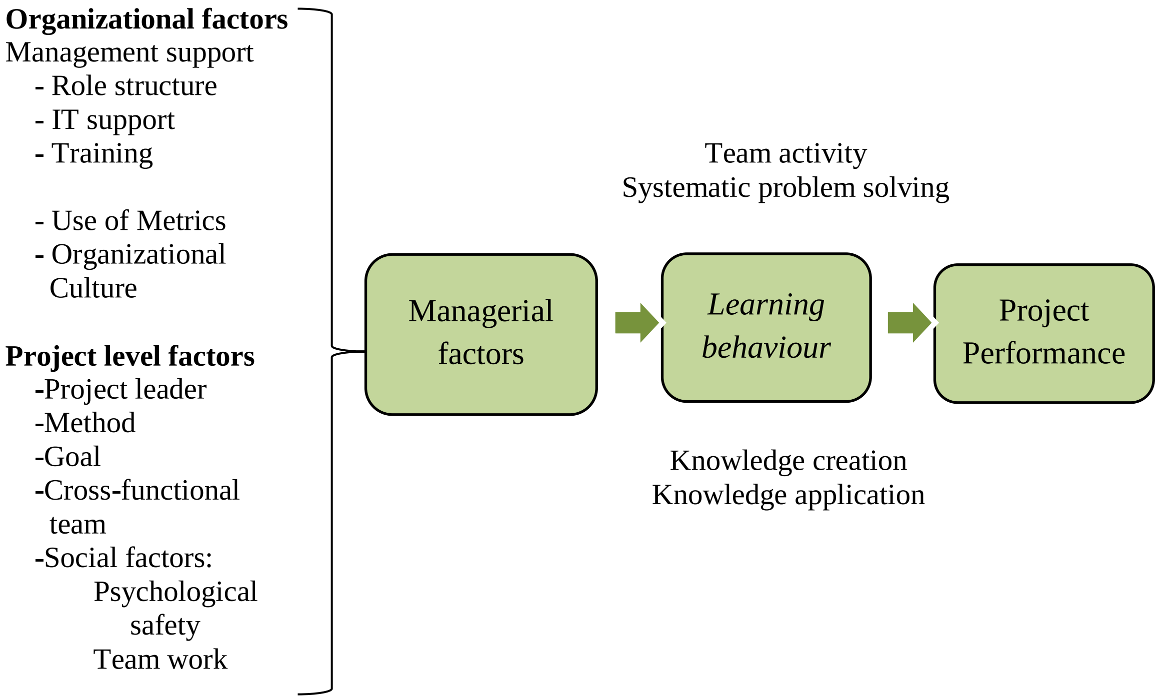

Figure A2 Conceptual framework

This research is undertaken towards the requirement of Ph.D. at the University of Strathclyde, Glasgow, UK. The first phase of the research is a survey research wherein data collection is done from two organizations deploying Six Sigma. The survey aims at collecting responses from project æeaders and members of Six Sigma projects. This second phase of the research aims to collect qualitative data from the selected projects from these two organizations, and compare the results from the survey research. Additional information is also collected from senior executives of the organizations on the nature and status of Six Sigma deployment and the functioning of project management. Further data, such as archives and observation at workplace are also carried out to get rich data for analysis and conclusions.

1. Unit of analysis

The interest for the present study lies in understanding learning processes empirically in Six Sigma projects. The researcher aims to understand the underlying activities and practices within Six Sigma project. Thus, *project is the unit of analysis* in this research.

2. Field procedures for Case study research

Data will be collected from deployment champions, one or two Senior management team members who are involved in Six Sigma deployment, and project leaders and members (at least two members) of the selected projects (MFG1 and MFG2). The data will be collected through a series of interviews, observations in plants/offices to witness the nature of the deployment, and by going through documents. Figure A3 displays phases of various steps of data collection and presentation. The following are the phases of the case study research planned:

Phase 1 Set up, Interview strategy

Phase 2 Conduct Interviews and recording data

Phase 3 Case study write up

Phase 4 Discuss case study with experts and with respondents/company representatives

Phase 5 Drawing evidence

Phase 1 Set up

- Investigate the nature of business and Six Sigma deployment in case study organizations.
- Financial and other administrative information (Six Sigma organization, development, etc.) gathered through online search and company web sites and from deployment champion.
- News and other information about Six Sigma deployment in the case companies
- Confidentiality - throughout the research confidentiality will be maintained both with the case study organization and the individuals participating in the interview. At the outset, the sponsors and all others from the participating organizations are ensured of this confidentiality. If required, a confidentiality agreement can be reached.

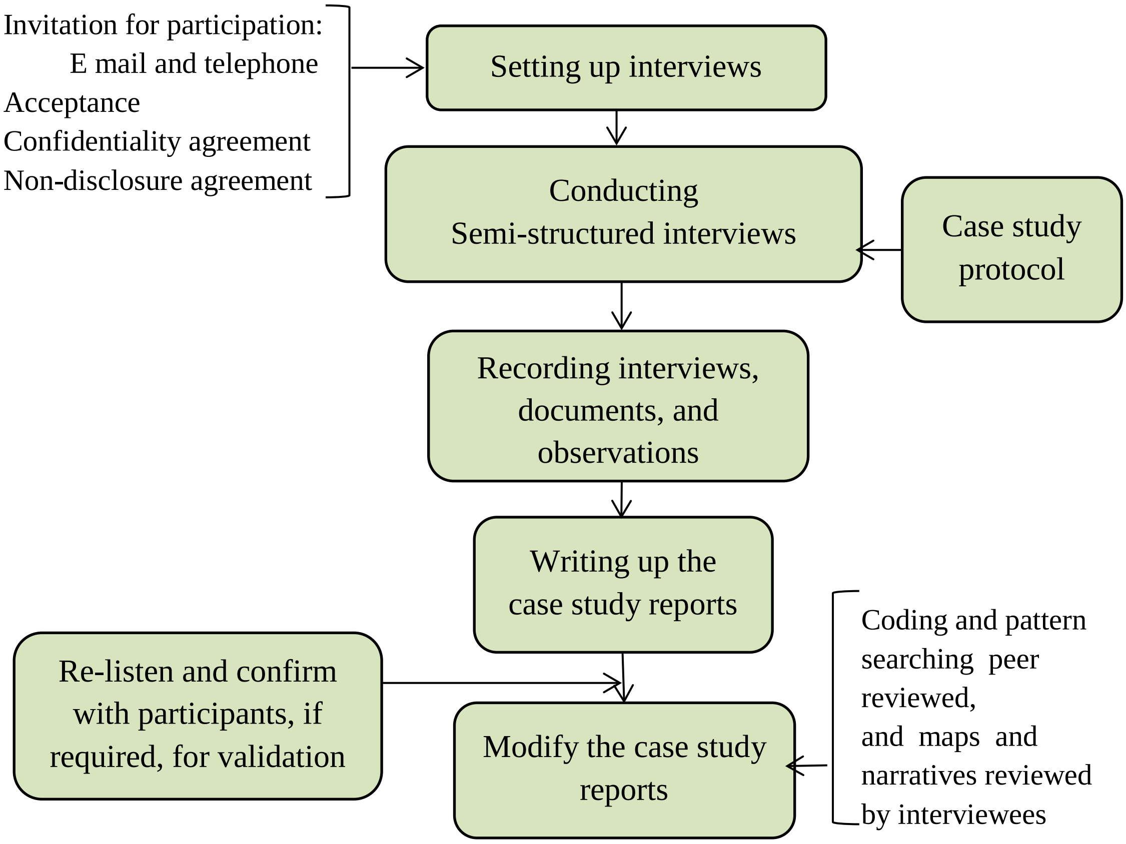

Figure A3 Phases of data collection and presentation

Documentation: The amount of documentation may vary from company to company. The aim is to get access to as much documentation as possible. Typical documentation required:

- Management information (e.g., KPIs, financial and other performance information related to Six Sigma)
- Organisational structures (how Six Sigma organization is positioned)
- Company communication - internal (Newsletter, Intranet, etc.) and external
- Any documentation that may relate to the deployment, such as, vision, mission, performance reports, management reports, strategy documents, management and company wide briefings, etc.
- Where an organization does not allow data to be taken away, note down important information from them
- Should documentation be obtained, it should be filed in a secure manner to ensure company confidentiality is maintained

As the case study research is the part of the sequential ‘‘*Quantitative → Qualitative*’’ mixed method research, the selection of projects to follow a systematic procedure. This is to ensure that the mixed method research provides credible and valid research findings. One study builds on another and hence, the quality of the inferences produced in one study may markedly affect the quality of the inferences generated in another study. The criteria would help to elaborate any unexpected results from the survey research and allow any new themes to emerge. Diverse contexts tend to provide more opportunities for checking alternative explanations and conducting multiple comparisons as various themes emerge. Get the acceptance from the participating companies to select projects as per the guidelines explained here

- Only those projects which have participated in the survey; typical, extreme or unique projects; projects which have reported extreme score on dependent variables; projects which have produced unexpected results (performance, extended project duration, etc.); and wide project topics

- Cases (projects) need to be interesting, to provide inspiration (case tells the story and concept emerges) and need to be illustrative. The sample case could be one of the extreme case, heterogeneous, homogeneous, critical and typical case
- In order to get heterogeneity in projects, sample projects to be selected from wide functions such as manufacturing, finance, maintenance, and purchase
- Select a balanced number of projects from best performed as well as below average performed projects (one or two failed projects also preferred)
- Projects having variation in project goal, team composition, leadership characteristics, project duration, project complexity, affected by things that are beyond the scope of the project teams and project performance (deliberate sampling for heterogeneity)

Phase 2 Conduct Interviews and recording data

A pilot case study

Conduct a pilot case study with three project leaders and two members of projects other than the sample projects in any one of the participating organizations. Identify if the questions work as intended. Based on the feedback from the interviewees, modify/add questions to the interview questions.

Conducting Interviews

Keep the following points in mind

- 3 to 4 interviews per day is a good guide if they are one hour long
- Try to allocate about 2 hours per interview to allow for time just to get to know each other.
- If needed, arrange for a follow up interview
- Leave a gap between interviews to allow time to reflect and prepare for the next interview
- Ensure (through the contact person) that the interviewees are well informed before they are due for an interview
-

Ensure that

- All interviews are recorded using electronic recording equipment – e.g. MP3 player, iPod, etc.
- Other mode of recordings can also be used: write up, cognitive mapping, mind-mapping or any other method preferred by the researcher
- Should maintain a research diary to facilitate the recording of all relevant observations

Appendix III A shows the semi-structured interview questions guide It covers interview guides for deployment champion, project leader and project team member.

Phase 3 Case study write up

Write up requires relistening to the interview recordings and analyzing company documents and researcher's notes and observations. The evidence from each case study will be documented in a detailed case study report. Reports need to contain the following:

- Introduction to the case in terms of the problem that the project trying to solve.
- Project goal
- Project leader and his skill level and experience in Six Sigma
- Team composition and number of members
- Project duration
- The performance achieved

The detailed analysis of each case under the following headings:

- Narratives
- Causal-maps
- Key findings
- Emerging themes /factors on learning and those affecting learnings and performance,
  and knowledge created, etc.

Phase 4 Discuss case study with experts and with respondents/company representatives

The researcher will then present the analysis and findings to other researchers/academics who have in-depth knowledge about Six Sigma and knowledge management in Six Sigma. In particular, any clarification regarding codings of learning behaviours should be settled by panel decision. Finally, narratives and causal maps to be sent to the respective case companies to verify the accuracy of the reports and maps by the respective project leaders The review process will ensure the research quality and reliability of data collected and presented in a consistent manner.

Phase 5 Drawing evidence

Based on the evidence from the data analysis, the research findings will be reported.

Appendix IIIA

Semi-structured Interview Questions Guide

(from Choo, 2003; Schroeder et al., 2008)

1. Deployment champion

Origin of Six Sigma deployment

- When, how, what were the major considerations/reasons for the deployment?
- How has Six Sigma evolved over time?
- What divisions in the company are using Six Sigma?
- What quality approach did Six Sigma replace, if any? (Lean/BPR/TQM. etc.)
- What are the benefits of Six Sigma over the prior approach to process improvement?
- Is Six Sigma likely to be permanent in your company?
- Did you have a vision, mission developed for Six Sigma and deployed throughout the organization?

Definitions

- How does the company define Six Sigma?
- What are the key elements (e.g., financial, specialists, etc.)
- Do you have different kinds of Six Sigma Approaches (e.g. Manufacturing, design, Transactional, software, service, etc.)?
- Is there a distinction between Six Sigma Projects and other projects in the company?

Approach

- How projects are selected and prioritized (criteria?)
- Are they linked to business strategy?
- Do you insist that the structured approach be used on each project?
- Do you have any specified approach (e.g. DMAIC or DMADV or ??)

- Is there a defined description of each step?
- What statistical tools fit into each step?
- Do you provide software support, such as MINITAB?
- What type of specialists do you have and what are their roles (e.g. GB, BB and MBB??)
- Do you have a Six Sigma organization established and if so how is it related to senior management team?
- Do you have reward and recognition systems in place? If so, how was it received by employees?

Resources/Training/Staffing

- How many specialists have you trained by year? (BB, GB, MBB)
- How many specialists are full time and part-time?
- How are specialists selected, trained and rewarded?
- What is the career path for specialists? Is someone hired to replace them?
- Describe the training program used for each level (get manuals if possible)
- What percentage of the company's business personnel are trained in Six Sigma?

Management Support

- How has top management supported and led Six Sigma?
- What is the role of management at other levels?
- Has there been resistance and problems implementing Six Sigma?
- Has it been difficult to keep momentum for Six Sigma going?
- Has there been management turnover? Would, or did, this create a problem?

Benefits

- What has been the financial payoff? (Total and by year, if possible)
- How financial results are projected, tracked and audited.

- What has been the benefit to customers? Give examples.
- Are there other benefits of Six Sigma?
- Are you having trouble quantifying intangible benefits, e.g. problems avoided, sales lost.
- Do you measure the overall Sigma Level of the organization for progress?
- Do you track Quality, Net Income, etc.?
- Has Six Sigma given you an advantage over the competitors? How?
- Is Six Sigma a “valuable resource” in the competitive arena?

Effect on Knowledge Creation

- How has Six Sigma affected knowledge creation? What kind of knowledge was created,
  and in what ways? Give Examples.
- What definition of knowledge are you using?
- Would you say that Six Sigma has led to tacit knowledge or explicit knowledge?
- To what extent the knowledge generated from Six Sigma is radical, incremental or both?
- How has Six Sigma affected individual and organizational learning? Give examples.
- Has most new knowledge come from groups or individuals?
- If Six Sigma was not used, would the knowledge have been created anyway? Why?
- How was knowledge created before you had Six Sigma?
- Does Six Sigma lead to organization wide knowledge and competitive advantage or is it largely localized and efficiency based?

Integrative Mechanisms for Knowledge Diffusion

- How is new knowledge related to existing knowledge?

- Has knowledge gained from Six Sigma been diffused beyond specific projects? (other business units, regions, subsidiaries, collaborators,…) What and how has it been diffused?
- Has knowledge created from Six Sigma been transferred by interpersonal relationships or formal mechanisms or both?
- If Six Sigma was not used, would the knowledge have been diffused anyway? Why?
- How was knowledge diffused before you had Six Sigma?
- Have there been any problems connecting knowing and doing?

2. Project leader

Origin

- What is the definition and content of the project?
- Where does the project fit into the company? Who was the champion?
- When, where and how did the project start? Who advocated it?
- Was the project considered strategic, why, how?
- Was there a focus on financial results?
- To what extent was there active senior management leadership?

Project Team/Method

- Who was involved in the project? Level, experience, role, etc.
- What was the involvement of project specialists?
- What project management approaches were used?
- What resources were available to the project?
- Describe the team approach used?
- What was done at each step? (e.g. DMAIC or DMADV- describe each step)
- Define activities data, tools used, time taken, who did it, etc.
  Define, Measure, Analyze, Improve, and Control.
- To what extent was the structured approach followed?
- What level of process sigma improvement was desired?

Project execution

- How he facilitated project execution;
- What are the activities team members carried out that helped to succeed project
- His activities that helped enhance the project performance
- How he supported team in problem solving
- What support he provided in improving team’s capability
- Can you please narrate contextual factors that impacted or inhibited project success?
- How the leader performed his role in focusing the project objective
- How team was motivated
- How he acted during difficult period,
- How far he could support from management for projects in terms of resources
- How they went about solving problem
- Difficulties faced and how they resolved?
- How team organized its work
- Challenges and uncertainty the team had to face
- How they went about the project through DMAIC?

Benefits/Costs

- What were the benefits and costs of the project, financial results?
- How did the project benefit the customer?
- What were the major milestones and how long did the project take?
- Did the project lead to competitive advantage or efficiency gains or both?
- What problems were encountered in conducting this project?
- Was there resistance to the recommendations and findings?
- What could be done, if anything, to make the project more successful?
- What lessons were learned?
- Did learning extend to other projects?

3. Members

Origin

- Was the project considered strategic, why, how?
- Was there a focus on financial results?
- To what extent was there active senior management leadership?

Project Team/Method

- Who was involved in the project? level, experience, role, etc.
- What was the involvement of project leader/specialists?
- What project management approaches were used?
- What resources were available to the project?
- Describe the team approach used?
- What was done at each step? (e.g. DMAIC or DMADV- describe each step)
- Define activities data, tools used, time taken, who did it, etc.
  Define, Measure, Analyze, Improve, and Control.
- To what extent was the structured approach followed?
- What level of process sigma improvement was desired?

Project execution

- How the leader facilitated project execution?
- What are the activities team members carried out that helped to succeed project
- Leader's activities that helped enhance the project performance
- How the leader supported team in problem solving
- What support the leader provided in improving team's capability
- Can you please narrate contextual factors that impacted or inhibited project success?
- How the leader performed his role in focusing the project objective
- How team was motivated by the leader?

- How the member acted during difficult period, and how the leader acted in that situation?
- How they went about solving problem
- Difficulties faced and how they resolved?
- How team organized its work
- Challenges and uncertainty the team had to face?
- What problems were encountered in conducting this project?
- How they went about the project through DMAIC?
- Did you refer to old projects/consulted/shared with other project teams?

Benefits/Costs

- What were the benefits and costs of the project, financial results?
- How did the project benefit the customer?
- What were the major milestones and how long did the project take?
- Did the project lead to competitive advantage or efficiency gains or both?
- Was there resistance to the recommendations and findings?
- What could be done, if anything, to make the project more successful?
- What lessons were learned?
- Did learning extend to other projects?
- Their own activities in enhancing their capability
- Narrate any specific actions that helped getting new insights about the problems they were investigating
- How team organized its work

Appendix IV

Academic publications and conference presentations

1. Journal Publications

Arumugam, V., Antony, J., Linderman, K. (2014), A multilevel framework of Six Sigma: A systematic Review of the Literature, Possible extensions, and Future Research. *Quality Management Journal*, 21(4), 36-61.

Arumugam, V., Antony, J., and Kumar, M. (2013), Linking learning and knowledge creation to project success in six sigma projects: An empirical investigation. *International Journal of Production Economics,* 141 (1), 388-402.

Arumugam, V., Antony, J., Douglas, A. (2012), Observation: A Lean tool for improving the effectiveness of Lean Six Sigma. *The TQM Journal*, 24 (3), 275-287

2. Conference papers presented

Arumugam, V., Antony, J. (2014), Influence of specialist project leader and structured method on Six Sigma project performance: an empirical study, *Fifth International conference on Lean Six Sigma*, Heriot-Watt University, Edinburgh, June 30-July1, 2014.

> *Received best conference paper award and a cash award of £50 from Emerald Publishers*

Arumugam, V., Antony, J. (2012), Role of goals on Six Sigma project performance through knowledge creation: A mediated moderation Analysis, *43rd DSI Annual meeting, San Francisco, USA: Nov 18-21, 2012.*

> *Received outstanding achievement award: Second prize in theory/empirical research paper (honorable mention)*

Arumugam, V. (2011), Six Sigma strategy and Absorptive Capacity: The effects of technical, psychological and contextual factors. *42nd DSI Annual meeting, Boston, USA: Nov 19-22, 2011.*

> *Received distinguished paper award: Best track paper award in Managerial Strategy and Organizational Behaviour/Theory-Certificate and $250 award*

Arumugam, V., Antony, J., Kumar, M. (2011), Organizational learning mechanisms in Six Sigma projects: An empirical study. *EurOMA Conference, Cambridge, UK, 3-6 July, 2011.*

Arumugam, V. (2011), Impact of Project Leader and Coach on the success of Six Sigma Projects. *3rd European Research Conference on Continuous Improvement and Lean Six Sigma,* Glasgow, UK, Jan 2011.

Arumugam, V. (2010), Lean tools for improving the effectiveness of Lean Six Sigma: A case study of “Observation”, *Second European Research Conference on Continuous Improvement and Lean Six Sigma*, Glasgow, UK, Jan 2010.
