ROLE OF GOALS ON SIX SIGMA PROJECT PERFORMANCE THROUGH KNOWLEDGE CREATION: A MODERATOR MEDIATION ANALYSIS

V.ARUMUGM
Strathclyde Institute for Operations Management
University of Strathclyde, James Weir Building, 75 Montrose Street,
Glasgow G1 1XJ, UK
E mail: aru.vela@gmail.com
Phone: +45 2568 0117

JIJU ANTONY
Strathclyde Institute for Operations Management
University of Strathclyde, James Weir Building, 75 Montrose Street,
Glasgow G1 1XJ, UK
E mail: jiju.antony@strath.ac.uk

ABSTRACT

We study empirically the impact of goals on Six Sigma project performance moderated by Tools/Method. Further, we propose that this moderated relationship is mediated by knowledge creation and evaluate the effect of moderation by simultaneously considering the mediation effect. The *mediated moderation* model was tested with data from 52 project teams using path coefficient analytical framework, incorporating both regression and path analyses. We found how the moderated variable influences direct, indirect, and total effects of our mediated model, and assessed the impact of goal on project performance at both low and high levels of Tools/Method in projects.

Key words: Six Sigma, goal, knowledge, performance, Tools/Method.

INTRODCUTION

Six Sigma is one of the well-established operations management strategies that has found wide applications for the last 20 years and claims to have benefitted a host of industries of all sectors and sizes (Antony, 2004; Schroeder et al., 2008). As the success of deployment solely depends upon the success of the improvement projects (Arumugam et al., 2012; Linderman et al., 2010; Schroeder et al., 2008), a considerable amount of research have recently focused more efforts on factors that affect project performance (Linderman et al., 2006, 2010; Choo et al., 2007; Arumugam et al., 2012; Zhang et al., 2008; Anand et al., 2011; Eston and Rosenzweig, 2012).

An emerging stream of research during the last few years in this area tries to explore and explain the Six Sigma phenomenon by invoking other management and behavioral theories and provides practical guidance for managers and Six Sigma practitioners. Goal setting theory (Linderman et al., 2003), Nonakka's knowledge management theory (Anand et al., 2010), absorptive capacity (Gutie´rrez et al., 2011), resource based view (Gowen and Tallen, 2005), and Institutional theory (Braunscheidel et al., 2011) are some of the perspectives borrowed from other management fields used in this stream of research.

Taking on goal-setting theory, which suggests that challenging and specific goals result in higher levels of performance than vague and non-quantitative goals, such as 'do-best goals' (Locke, 1968; Locke and Latham, 1990), Linderman et al. (2003) proposed a goal-theoretic model of Six Sigma that suggests that specific and challenging Six Sigma goals lead to more team member effort, persistence and direction than vague goals, resulting in improved performance level. Subsequent empirical investigation established that goals can be effective in Six Sigma improvement teams when team adheres to the Six Sigma Tools/Method (Linderman et al., 2006). However, no other studies till date have replicated this research, which is quite surprising, given the fact that challenging goal is one of the special characteristics of Six Sigma deployment (Pande et al., 2000; Harry and Schroeder, 2000).

Scholars have acknowledged the importance of knowledge management in Quality management (Hackman and Wagemen, 1995; Sitkin et al., 1994) and assert that learning is vital especially in problem solving environments such as Six Sigma which provides a positive and conducive environment for deliberate learning (Anand et al., 2009: Arumugam et al., 2012; Llore´ns-Montes and Molina, 2006; Linderman et al., 2010) and forms a dynamic capability (Anand et al., 2009). Two recent empirical studies in Six Sigma project context have found evidence on the mediating effects of learning and knowledge creation on the effects of project level and organizational level factors on project performance (Choo et al., 2007; Arumugam et al., 2012).

Goal setting theory is also widely used to explain learning motivation (Pintrich and Scunk, 1996). Locke et al. (1981) argue that hard goals may only improve performance if they lead to effective strategies. Strategy development is motivated by goals and it refers to action plans for attaining ones goal and it involves skill development or creative problem solving in teams that involves learning and knowledge creation.

In order to bridge the gaps found in the literature, the present study investigates empirically the impact of goals on project performance by proposing an extended model (Figure 1), incorporating knowledge creation as a mediator in the original model of Linderman et al. (2003, 2006).

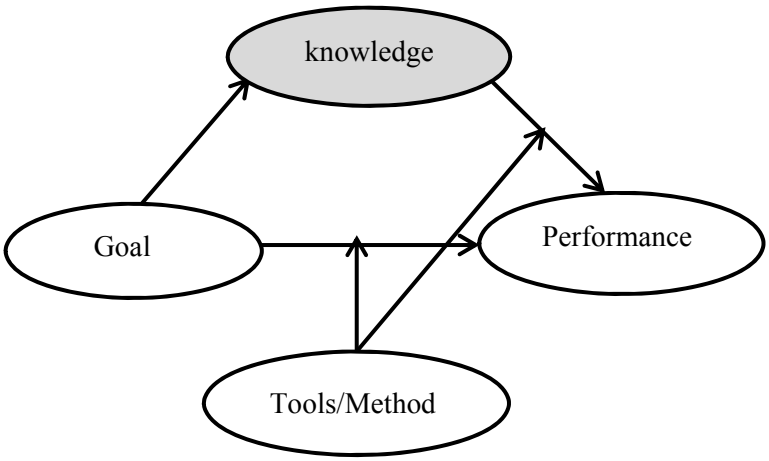


Figure 1. Research model

The proposed *mediated moderation* model suggests that Tools/Method have moderation effects on goal and the moderated path is mediated by knowledge which in turn is moderated by Tools/Method to impact project performance. We used regression analysis and analytical

framework for testing mediated moderation model proposed by Edwards and Lambert (2007). We estimate the path coefficients and in turn find the impact of goal on performance both at low and high Tools/Method application. This analytical method overcomes many methodological problems faced by current methods found in the literature for mediated moderation effects.

The primary objective of the study is twofold. First objective is to replicate the earlier research on goal theoretic perspective of Six Sigma in a European context. Second, this study extends the earlier study by considering knowledge creation as a mediator in the research model. Specifically our study seeks to advance our theoretical understanding of Six Sigma phenomenon through goal setting theory of applied psychology literature and knowledge framework.

THEORY DEVELOPMENT

Six Sigma, goal and Tools/Method

Invented by Motorola, Inc. in 1986 as a metric for measuring defects and improving quality, Six Sigma has evolved to a robust business improvement strategy that focuses an organization on customer satisfaction (Antony, 2004; Harry & Schroeder, 2000; Schroeder et al., 2008). In Six Sigma, process improvement projects are identified, selected, and prioritized and executed. Each project team is led by a project leader who is specialized in Six Sigma methods, tools and techniques (Black Belt or Green Belt level in skill). Team carries out project by following a structured approach or method called DMAIC, which stands for Define, Measure, Analyze, Improve and Control. DMAIC phases are mutually reinforcing and interconnected and each of which is recommended with proven quality tools including advanced statistical ones (Goh, 2002; Breyfogle, 1999; Hoerl, 1998). This method parallels to PDCA (Plan-Do-Check-Act) cycle (Schroeder et al., 2008; Deming, 1986; Shewart, 1939).

DMAIC method starts with defining what needs to be improved and what is important to customer. These *Critical To Quality* (CTQ) characteristics are measured and analyzed and based on the base-line performance, improvement goals are set. Six Sigma is known for employing challenging goals (Harry and Schroeder, 2000; Linderman et al., 2003; Pande et al., 2000). In organizations deploying Six Sigma, base line performance of processes are usually measured in terms of Defect Per Million Opportunities (DPMO) level, where defect opportunities is a process failure that are critical to customer. The DPMO levels are further expressed in terms of Sigma level. 6 Sigma, for example, refers to 3.4 DPMO and this challenging goal is far beyond normal quality levels and required very aggressive improvement efforts (Linderman et al., 2003). Working with the challenging goals requires more efforts on the part of the project team.

Goal setting theory and Performance

Goal setting theory states that specific difficult goals yield higher performance than nonspecific (do-your best) goals, and specific difficult goals yield higher performance than specific easy goals (Locke and Latham, 1990). Goal theory also applies to group goals (Locke and Latham, 2002; Weldon et al., 1991) and recent quantitative meta-analyses by O'Leary-Kelly et al. (1994) and Kleingeld et al. (2011) have supported this view.

Goals are immediate regulators of human action (Locke et al., 1981). Researchers view goal setting primarily as a motivational mechanism, though cognitive elements are necessarily involved. The motivational mechanism explains that challenging goals mobilize effort, direct

attention, and encourage persistence and strategy development (Locke and Latham, 1990) and these mediators are well documented in the behavioral and applied industrial psychology literature (see Locke & Latham, 1990, 2002 for a thorough review).

If goals are considered unattainable, team members may not exert more efforts which would decrease performance (Locke and Latham, 1984; Erez and Zidon, 1984: quoted by Linderman et al., 2006). Based on the research review, Locke and Latham (1990) argue and conclude that in general, difficult goals result in increased levels of performance, however, if they become too difficult, a drop in performance occurs. Citing OM scholars' arguments (e.g. Bendoly and Hur, 2005) that bipolar relationship is most suitable while applying behavioral theories to operations management phenomena, Linderman et al., (2006) posited bipolar (non-linear) relationship between goal and performance.

Thus our first hypothesis, due to Linderman et al. (2006):

> **H1:** Challenging and specific goals used in Six Sigma project improvement team has a curvilinear relationship (an inverted U shape) with project performance, with a moderate level of goal produces high project performance.

Goal, knowledge creation and performance

Locke and Latham (1990) assert that goals activate knowledge and skills that the individual possesses that are perceived relevant to the task. In Six Sigma context, Linderman et al. (2003) have stated that goal serves as regulators of human action by motivating the members to engage in learning activities that create knowledge and help make improvements. Goal setting is an important component of social learning theory (Bandura, 1977) and learning motivation can also be explained by Bandura's self-efficacy theory. The team member's self-efficacy determines the goal level, commitment to goal, selection of task strategies including learning with which to attain the goal, degree of effort and performance (Bandura, 1977; Stevens and Gist, 1997; Jiwani and Wood, 1991).

Challenging improvement goals motivate team members to engage in deliberate learning activities that create knowledge and make improvement (Linderman et al., 2003; Choo, 2011; Arumugam et al., 2012). Choo et al. (2011), for example, found empirical evidence to show that the sense of challenge created by stretch goal, positively impact knowledge creation.

In Six Sigma project team, consisting of members from different functions, learning behavior includes discussions within the team, seeking knowledge from outside the team, and sharing knowledge among them (Pande et al., 2000; Pyzdek, 2003; Arumugam, 2011; Anand et al., 2010; Arumugam et al., 2012). Project team leader through his actions, gathers and synthesizes individual knowledge to create team level knowledge leading to enhanced project performance (Arumugam, 2011; Anand et al., 2010; Sarin and McDermott, 2003).

Past research has shown that shared interpretation of knowledge mediates the effect of knowledge dissemination toward process improvement (Huber, 1982; Hult et al., 2004; Fugate et al., 2009). Past empirical research in Six Sigma project context has also shown that the success of the process improvement team depends on the knowledge that the team members develop during the execution of the project and apply those gained knowledge appropriately for project success (Anand et al., 2010; Choo et al., 2007; Arumugam et al., 2012).

Based on the above arguments, we offer:

> **H2:** Knowledge creation in project team mediates the relationship between goal and project performance.

Tools/Method as a moderator

A specific difficult goal, for example, can direct attention towards both the activity to be performed and the results to be obtained by the team (task strategy). If the goal is only *do-it* type, effort taken simply translates directly into performance. For simple tasks, goals affect performance mainly via motivational mechanisms, while complex tasks such as those with challenging goals require the development and implementation of effective task strategies.

The team with hard specific goal may fail to cover all the task aspects and outcome. If the team, for example, focuses on some aspects of the task and the outcome, leaving one or more important aspects of task, then it is likely that goal leads to inappropriate or poor performance strategy (Earley et al., 1989; Huber, 1985). Thus, goal setting can facilitate or hinder performance, depending on whether the process it produces such as motivation and task strategies is appropriate for the task at hand (Mitchell and Silver, 1990). Past research has supported this view. Wood et al. (1987) for example, through a meta-analysis established that goal-setting effects are less strong for complex tasks than for simple tasks. In a related research, Earley et al. (1989) found that specific difficult goals do less well than easy or do-your-best goals on novel decision-making tasks. Similarly Campbell (1984) and Huber (1985) have shown that specific difficult goals may result in lower performance on complex tasks than do easy goals.

Linderman et al. (2003, 2006) argue that using quality improvement tools and methods should reduce the task's complexity by guiding the search for solutions to complicated problems as method such as DMAIC helps break down the complex task with challenging goal into elementary manageable components and reduces the task complexity (Linderman et al., 2003, 2006). Use of tools and techniques should alter their ability to achieve challenging goals. The authors' empirical investigation also shows positive interaction effect between goals and Six Sigma Tools/Method with performance (Linderman et al., 2006).

Therefore, our third hypothesis due to Linderman et al., (2006):

> **H3a:** The degree of adherence to Six Sigma Tools/Method positively moderates the effect of goal on project performance

A team with challenging goals needs to process additional technical and conceptual information and develops new ways of carrying out the project (Brown and Utterback, 1985; Dewar and Dutton, 1986) and tools help the team to see the problem through data, scientifically analyze the problem through logical reasoning and help gaining increased knowledge to arrive at an optimal solution.

The Method brings together different sources of expertise (Arumugam et al., 2012; Nair et al., 2011), increases lateral interactions between areas of functional knowledge (Gupta and Govindarajan, 2000), positively influences acquisition and assimilation of new external knowledge (Jansen et al., 2005), helps to overcome differences, interpret issues, build understanding about external knowledge (Daft and Lengel, 1986; Cohen & Levinthal, 1990; Morrison, 2002), facilitates coordinated work among team member, and helps teams work toward own performance and others to achieve overall group performance (Sinha and Van de

Ven, 2005; Van de Ven et al., 1976). Project leader gathers individuals' knowledge and synthesize into team level knowledge to identify solutions to the problem (Arumugam, 2011; Anand et al., 2010; Sarin and McDermott, 2003). Adhering to DMAIC method thus facilitates the team to attain problem solving skills, to understand the process behavior through various tools and techniques that are embedded within DMAIC phases, to deduce causal relationships between variables by making use of various tools and techniques and finally to implement far-reaching adaptations, including modification of process for improved outcome (Arumugam et al., 2012).

We expect, therefore, the application of gained individual knowledge and conversion into team level knowledge and application of that knowledge for process improvement depends on the level of adherence of Tools/Method. This leads to our next hypothesis:

> **H3b:** The degree of adherence to Six Sigma Tools/Method positively moderates the effect of knowledge on project performance

Overall, the model (Figure 1) signifies that the strength of the goal-knowledge-performance relationship is dependent on the level of Tools/Method. The model posits that Tools/Method alters positively the way goal affects performance through knowledge creation.

RESEARCH METHOD

Our unit of analysis is Six Sigma project team. Consistent with a theoretical sampling approach (Eisenhardt, 1989), our primary data for this study was collected from a Six Sigma organization, a high tech engineering company (hereinafter called as EMFG) having its head quarter in a European country. EMFG is a fortune 500 company with over 40,000 employees worldwide. It has had Six Sigma deployment for more than 5 years. EMFG employs DMAIC for manufacturing related projects and DfSS (Design for Six Sigma) for design related projects. The data used in this study is part of the larger survey. We selected all 110 completed projects carried out through DMAIC methods during the last two years in one of their business units. Recent projects help to minimize measurement error due to recollection effect. A web-based survey found in similar studies (Linderman et al., 2006; Anand et al., 2010; Choo et al., 2007) was used. The Six Sigma deployment Champion sent personalized e-mails to all members and leaders of the 110 projects along with the survey links. Reminder and thank-you e-mails were sent every week until we received a satisfactory response rate.

We obtained usable response from 52 projects, a 47.3% response rate. In total, we had 158 people participated in the survey. Black Belts led 23 projects and the rest by Green Belt specialists. The team size varies from 3 to 9 members. A two-sample t-test showed no variation between early and late response (Lambert and Harrington, 1990). The study looked into the completed projects only. The data for each project is based on responses from project leader and at least two team members from each project. Multiple respondents helped to minimize common method bias and increased triangulation and instrument validity.

Measures

Reliabilities of all measurement scales exceeded the recommended 0.7 (Nunnally and Bernstein, 1994), except that of goal scales. Most of the scale items were taken or adapted from the validated scales from earlier empirical studies. Scale items captured the extent to which the respondents agree using a 7 point scale from strongly disagree to strongly agree. Academicians and practitioners reviewed new scale items for refinement and pilot survey ensured content validity (Rungtusanatham, 1998; Churchill, 1979).

Goal (Cronbach α = 0.64) -3 items scale measures the extent to which goals were specific, challenging and strategic important representing customer requirement. One item was taken from Linderman et al. (2006) and two items were newly developed based on the literature review. ***Tools/Method*** (Cronbach α = 0.87) - 4 items scale, 3 items from Linderman et al. (2006) and one item newly developed. Scale measures the extent to which Tools/Method were adhered to. ***Knowledge*** (Cronbach α = 0.89) - 3 items scale from Choo et al. (2007), measures the degree of solution uniqueness, idea generation, and improved understanding and capability of the team members. ***Project Performance*****:** All the 4 items of the scale (Cronbach α = 0.90) are from Linderman et al. (2006). The scales measured the extent to which customer satisfaction, cost benefit and strategic impact of the organizations were achieved in each project.

Confirmatory factor analysis (CFA) was conducted for the three factor structure consisting of goal, knowledge and Tools/Method comprising ten items. The model fit was found to be extremely well (χ^2/df =1.05, df = 30, probability 0,265, RMSEA= 0.05, GFI = 0.89, TLI =0.98, CFI =0.99) with all values within the acceptable limits (Hu and Bentler, 1999). Item loadings were as proposed and were significant (p< 0,001), providing evidence for convergent validity (Bagozzi and Yi, 1991).

ANALYSIS AND RESULTS

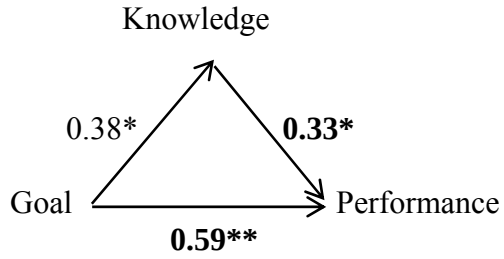
Size of the team, project duration and leader's project experience were controlled for in the analysis. To test our hypothesized model, we followed Edward and Lambert's (2007) approach for mediated moderation analysis. In this approach moderated regression approach is combined with testing mediation in a path analytic framework to supplement Baron Kenny's (1986) 3-step causal steps (Edward and Lambert, 2007; Tepper et al., 2008).

Hypothesis 1 predicted that the challenging and specific goals used in Six Sigma project improvement team has a curvilinear relationship (an inverted U shape) with project performance, with a moderate level of goal produces high project performance. The coefficient for the goal quadratic term (Goal²) was not significant and thus hypothesis 1 was not fully supported, and only linear relationship was found between goal and performance and this finding is consistent with Linderman et al's (2006) finding.

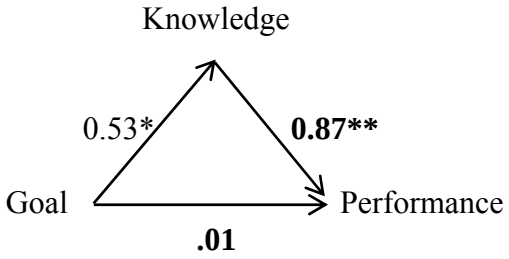
Hypothesis 2 which predicted that knowledge would partially mediate the effect of goal on project performance was tested using Baron and Kelly's (1986) 3 step method and the results supported the hypothesis. Hypothesis 3a predicted that Tools/Method would interact positively with goal in influencing its relationship with performance and H3b predicted that Tools/Method would interact with Knowledge in impacting its effect on performance. Both these hypotheses were supported.

In order to better integrate moderation and mediation and assess the impact of goal on project performance in the context of moderation by Tools/Method and partial mediation by knowledge, we followed the path analysis procedures proposed by Edward and Lambert (2007).

Using this analytical procedure, we assessed direct, indirect and total effects of goal on performance, at low (one standard deviation below the mean) and high (one standard deviation above the mean) levels of the moderator variable (Tools/Method) and are depicted in Figure 2.



A. Simple effects for low Tools/Method



B. Simple effects for high Tools/Method

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

Figure 2 Mediated models showing simple effects of Low and high Tools/Method. Path coefficients in bold face were significantly different ($p<0.05$) across levels of the moderator variable (Tools/Method).

These results are consistent with our H2, H3a and H3 and our hypothesized model showing the existence of mediation by knowledge on the relationship between goal and project performance, and the existence of moderation by Tools/Method only on the linkage between goal and performance (direct effect) and between knowledge and performance (second stage of the indirect effect).

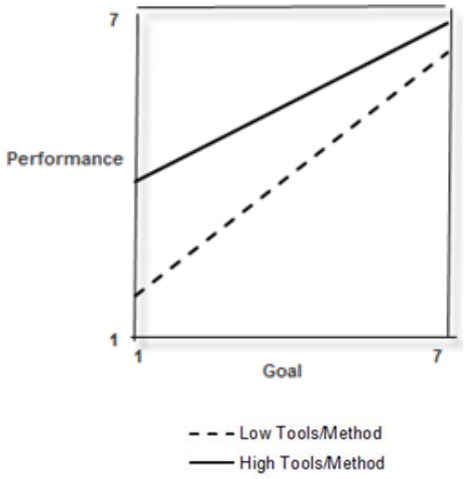


Figure 3. Total effect

DISCUSSION

Replication implies that results can be generalized with confidence, and it helps building the foundation for theory development. By taking samples from a European country, our research setting indeed focuses a different context indirectly. With the exception of enhancing measures of goal variable (Cronbach alpha of the original goal scale was 5.9 and our improved scale has a value of 0.64), however, the present study tried to replicate as closely as possible to the original study.

Though our result found empirical support that goals do in fact affect performance positively, it fails to show the curvilinear relationship as hypothesized, but consistent with Linderman's finding. It is quite possible in our data set coming from a single organization, that the

perception of the respondents on goal level and performance may be higher than the actual level on a comparative standard. Future replication with data from multiple organizations with varying goal levels may throw more insights into this phenomenon, and can inform whether the curvilinear relationship can be applicable to process improvement group setting.

We extended the theoretical model of Linderman et al. (2003), by incorporating knowledge as a mediator in the goal-performance relationship. For the first time in QM literature, the present research empirically supports this view and shows that goal has significant positive influence on learning and knowledge creation in quality/process improvement teams. Specifically, our research merges the goal theory literature with knowledge framework to explain the mediating mechanism of knowledge. Our research provides a new lens to investigate the effect of goal on performance of quality and process improvement projects.

Majority of the empirical studies in Goal setting theory in applied psychology focus on individual goals (Locke and Latham, 1990; Kleingeld et al., 2011) and most of the studies on group goals focus only on stable work teams or class room experimental teams. Field studies on group goal setting are a challenging endeavor and are very rare in applied psychology research discipline (Kleingeld et al., 2011). Our present study by taking group perspective similar to Lindeman et al.'s (2006) study (problem solving groups), and incorporating knowledge in the model, has advanced the research in group goal and thus contributes to Goal setting theory literature.

This finding provides an important complement to existing work on performance capabilities due to team learning such as new product development (Sarin and McDermott, 2003), hospital improvement team (Tucker et al., 2007; Pissano et al., 2001), and Six Sigma process improvement (Choo et al., 2007; Arumugam et al., 2012; Choo, 2011; Anand et al., 2010).

The result suggests that when Tools/Method is high, the effect of goal on performance is mainly through knowledge. The finding reveals that high Tools/Method encourages learning and knowledge creation which is consistent with earlier findings of Choo et al. (2007). Given the short duration of Six Sigma projects, the possibility that the team may be inclined to spend too much time in learning instead of focusing on task aspects toward successfully completing the project when Tools/Method adherence is high is worthy of further investigation. Given the findings here, it would be worthwhile to study the factors that influence such choices.

The findings on the total effects suggest that, overall, performance was higher across all levels of goal for high Tools/Method (Figure 3), although the effects of low Tools/Method was stronger. This finding on high Tools/Method is contrary to the finding of the original study which has found that high Tools/Method results in higher performance except when goals are low. Researchers attributed this anomaly to the excessive use of Tools/Method for low goal projects. Further, they stated that these low-goal projects should have been *Do-it* projects that do not need any root cause analysis requiring DMAIC approach (Linderman et al., 2006: pp.786). On the contrary, our sample projects, as per the Six Sigma Champion of our participating organization, are Six Sigma projects characterized by challenging goals. Hence the difference in findings reported here from that of the original study can be attributed to the nature and types of the projects.

Overall, the replication supports the theory that goal positively affects performance and Tools/Method moderates the effect of goal on performance. But this need to be understood in the context of the knowledge created by the team and our alternative moderated mediation model gives a more nuanced understanding of these relationships.

Our findings suggest that Tools/Method adherence in projects has a positive reinforcement effect on goals. In order to obtain optimal performance in improvement projects, effective utilization of Tools/Method, hence, is required. This research points to the practicing managers that setting challenging goals without fully providing resources for training on tools and techniques and methods can lead to sub-optimal results.

We have shown that goal impacts performance through learning and knowledge creation (mediation effects) and hence, providing environment conducive for learning can lead to enhanced project performance. This research points to managers through empirical support, that challenging goals enhance deliberate learning in improvement project teams and in turn organizational learning.

CONCLUSION

By replicating the earlier study on goal theoretic perspective of Six Sigma phenomenon in a different population for the first time, this study informs how far the results of the study are generalizable to another population. We introduced in our replication, a new conceptual relation that helps to develop the theory further and found that the newly introduced variable, knowledge, has significant effect on the goal-performance relationship. Thus our study has helped to add new insights to the existing stock of knowledge and provides conceptual extension (Tsang and Kwan, 1999) to the goal theoretic model of Six Sigma.

The paper provides an interdisciplinary treatment of knowledge management in process improvement and demonstrates how Six Sigma project teams promote deliberate organizational learning. The findings support the knowledge based view of firm which assumes that knowledge leads to performance. The study provides empirical support to enrich our understanding of Six Sigma phenomenon through Goal setting theory of applied psychology literature and knowledge framework and contributes to both Operations Management and Team learning literatures. By advancing goal theory research in a non-stable group setting (problem solving groups) and by including knowledge in the model, this study also contributes to the goal setting theory literature.

References available from the authors