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Software Quality Skills in CMM-Based Development Environments

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Abstract

This paper examines the complex software development environment in which IS professionals commonly function today. Skills and competencies appropriate to this environment are increasingly related to managing change and adopting change agent roles. These skills and competencies are discussed in relation to complex and changing environments. A survey of IS professionals evaluates their perceptions of the importance of these competencies and their own capability in these areas. Observations and conclusions in this paper are primarily drawn from research on organizations that have initiated software process improvement initiatives (McGuire 1996a; 1996b; 1997).

Introduction

The growing global economy for software products and services has driven many organizations to redefine the very paradigms by which they operate. A larger and more demanding customer base, the necessity for reduced cycle time, the growing complexity of software systems, and the increased mission-critical status of these software systems are only some of the factors that are pressuring organizations to deliver higher quality, more complex software products in the face of an ever turbulent and competitive global environment.

According to Waldrop (1992), many organizations are operating at or approaching the "edge of chaos" as the complexity of their environment increases and as the metabolic rate of their functions and processes escalates to keep pace. "The edge of chaos is where new ideas and innovative genotypes are forever nibbling away at the edges of the status quo, and where even the most entrenched old guard will eventually be overthrown....The edge of chaos is the constantly shifting battle zone between stagnation and anarchy, the one place where a complex system can be spontaneous, adaptive, and alive." (Waldrop 1992, p. 12).

Managing Complex Change

It would appear that if an organization is operating at or near the "edge of chaos" that traditional models of managing innovation and change within that organization are quickly becoming outmoded. The literature shows a strong call for new models of change management that are more appropriate for organizations operating in complex, chaotic environment.

Orlikowski and Hofman (1997) note that traditional models of change as characterized by Lewin's three-stage model of "unfreezing, change, and refreezing" are appropriate only for organizations that are relatively stable and bounded and whose functionality is fixed. These models, however, are not appropriate in the more turbulent, flexible, and uncertain organizational and environmental conditions that often exist today.

Orlikowski and Hofman suggest that a more appropriate way of thinking about change would be an approach that reflects the "unprecedented, uncertain, open-ended, complex, and flexible nature of the technologies and organizational initiatives involved." Such a model, they note, would enable organizations to systematically absorb, respond to, and even leverage unexpected events, evolving technological capabilities, emerging practices, and unanticipated outcomes.

New change models suggest the need for new roles for change agents. Markus and Benjamin (1996) have recently addressed the need for an expanded definition of the traditional model of IS change agency. They conclude that the traditional IS model wherein the IS change agent views the technology as the agent of change is rapidly becoming unviable. They note that IS professionals need to become better organizational change agents "because change agency will most likely become the largest and most important part of interorganizational IS work in the future" as more information technology is implemented into organizations.

One area in which IS professionals are finding new challenges today is that of software process improvement. With the focus equally on people, process, and technology, effective software process improvement initiatives require IS professionals to have the ability to acquire and use an expanded skill set within a fast-cycle software development project operating in a highly complex and changing organizational environment.

Nonlinearity in Software Development Organizations

Nonaka and Takeuchi (1995) address the successful management of the new product development process that is characteristic of software organizations. They state that organizations must maintain a highly adaptive and flexible approach to new product development because it rarely proceeds in a linear or static manner and instead involves an iterative, dynamic, and continuous process of trial and error. They cite the software industry as best embodying this spiral approach and reference a

recent study by Cusumano and Selby (1995) showing that software developers move around in phases, iteratively designing, coding, and testing as the project progresses.

In addition, Nonaka and Takeuchi believe that self-organizing project teams should oversee new-product development. Organizations should be willing to give a high degree of autonomy to such teams especially as they cope with ambiguity, fluctuation, and creative chaos in the startup phases of new-product development where little prior knowledge exists and taking initiatives and risks are necessary.

Nadler (1992) views the future organization in much the same way. One of the characteristics becoming prevalent for organizations is that organic, adaptable teams will be the norm at all organizational levels. Not only will this provide the capability for faster response time but these teams will be relatively autonomous in comparison to previous organizational eras.

Leonard-Barton (1995) sees much the same thing happening to organizations. Certain types of tool implementation such as intensive codevelopment with user groups leads to opportunities for *mutual adaptation* of both technology and user work environment. Mutual adaptation is the reinvention of the technology to conform to the work environment and the simultaneous adaptation of the organization to use the new technical system. Nonlinearity and higher-order learning (learning beyond the current operating level and problems of the organization) become organizational norms.

The concept of organizational nonlinearity is also explored by Goldstein (1994) who describes one of the advantages of a nonlinear system as its potential for self organization since change does not need to be imposed but just released under appropriate conditions. Linear systems, in contrast, do not have this potential. He notes that the radical organizational change that strategies such as reengineering, cycle time management, concurrent engineering, TQM, and continuous improvement call for are more congruent with the spontaneous system reorganization of nonlinear systems than with the more stable nature of linear models. He reasons that if organizations are nonlinear, then only a nonlinear strategy takes advantage of organizational nonlinearity with its evolutionary potential.

Nonlinearity is also seen as the norm in software development by Olson (1993) who argues that "highly detailed linear development processes" don't match the way real software development is done but plans and schedules are nevertheless constructed according to this model. He states that the failures in software development are the result of applying valid and significant disciplines (such as linear process models) in areas where the base assumptions of the disciplines don't match the problems that are to be solved or the organizations that are involved.

Olson believes that software development is characterized by a chaotic approach where "there's always another way. You should achieve a fit between the discipline, the problem, the people, and the organization." (p. 54). He claims that the fundamental stages of software development such as problem solving, requirements gathering, system design, user interface design, coding and data structures are all chaotic in nature as they involve multiple iterations and feedback loops that result in a maturing sequence of mental models. The progression from model to model, he states, is not linear but instead proceeds in fits and starts as software developers study and worry about problems, find solutions, and then discover new problems.

Within these increasingly complex organizational and software development environments there is a call for higher quality and reliability in software systems. Software process improvement issues have recently gained much visibility in the industry and software professionals are being asked to adopt new work practices in addition to working in complex environments.

Competency Needs of IS Professionals

New competency needs of IS professionals will be shaped by the complex organizational and systems development environment discussed above. A summary of desirable competencies includes:

Communications: IS professionals must communicate in a variety of settings using oral, written, and multimedia techniques. Change agent roles, in particular, require the ability to effectively articulate both strategic and tactical planning to multiple levels of an organization during the life cycle of a project or program.

Problem Solving: IS professionals must be able to choose from a variety of different problem solving methodologies to analytically formulate a solution. IS professionals must be able to work on project teams and use group methods to define and solve problems.

Organization and Systems Theory: IS professionals must be grounded in the principles of systems theory. IS professionals must have sufficient background to understand the functioning of organizations since the information system must be congruent with, and supportive of the strategy, principles, goals, and objectives of the organization. IS professionals must understand and be able to function in the multinational and global context of today's information dependent organizations.

Quality: IS professionals must understand quality, planning, steps in the continuous improvement process as it relates to the enterprise, and tools to facilitate quality development. As the IS field matures, increasing attention is being directed to problem avoidance and to process simplification through reengineering. Error control, risk management, process measurement and auditing are areas that IS professionals must understand and apply. IS professionals must possess a tolerance for change and skills for managing the process of change.

Groups: IS professionals must interact with diverse user groups in team and project activities. IS professionals must possess communication and facilitation skills within team meetings and other related activities. IS professionals must understand the concept of empathetic listening and utilize it proactively to solicit synergistic solutions in which all parties to an agreement can benefit. IS professionals must be able to communicate effectively with a changing work force.

Competency Survey

A survey of IS professionals currently working on software development projects was conducted to determine their perceived needs in some of the above competencies. This survey asked participants to rate their perception of their current

capability for each of 20 items on a scale of 1-5 and also asked for their rating of how important they regarded that item in their current work environment, again on a scale of 1-5. Respondents were working on various projects in a large application development contracting organization.

Table 1. Ranking of Current Capabilities	
<i>n = 114</i>	
Group Decision Making	— 2.3
Conflict Resolution	— 2.1
Business Domain Knowledge	— 3.6
Risk Analysis	— 2.4
Process Control Tools	— 1.5
Intergroup Coordination	— 3.7
Negotiating	— 2.2
Change Management	— 2.8
Teamwork Behaviors	— 3.8
Metrics and Measurement	— 2.3
Customer Focus	— 2.6
Process Definition	— 2.1
Process Focus	— 2.3
Quality Focus	— 3.9
Project Management	— 4.1
Interpersonal Communication	— 3.8
Organizational Learning	— 2.4
Technology Transfer	— 2.5
Change Advocacy	— 1.7
Strategic Alignment	— 1.5

Table 2. Ranking of Perceived Importance	
<i>n = 114</i>	
Group Decision Making	— 4.2
Conflict Resolution	— 4.3
Business Domain Knowledge	— 4.7
Risk Analysis	— 3.6
Process Control Tools	— 3.2
Intergroup Coordination	— 3.9
Negotiating	— 3.8
Change Management	— 4.7
Teamwork Behaviors	— 4.6
Metrics and Measurement	— 4.1
Customer Focus	— 4.8
Process Definition	— 3.5
Process Focus	— 3.7
Quality Focus	— 4.8
Project Management	— 4.8
Interpersonal Communication	— 4.0
Organizational Learning	— 3.9
Technology Transfer	— 4.3
Change Advocacy	— 4.2
Strategic Alignment	— 4.1

The results of these surveys indicate that IS professionals recognize the importance of factors associated with the organizational and software development environments characterized by complexity and change. The results also indicate that IS professionals perceive their individual competencies in these areas to be relatively low thus hindering their ability to be effective change agents in these environments.

These survey results support the view that the software development environment is changing and that additional and/or enhanced competencies are required for IS professionals to effectively operate as change agents in this environment. Organizations need to address these needs to effectively prepare their current workforce to be successful in the complex and changing development environments that are already common and may well become the norm within a few years.

Conclusion

Successfully implementing process improvement efforts requires attention to many organizational, people, process, quality, and methodological issues. The factors discussed in this paper are directly applicable to technical environments where software professionals are facing increasing demands for higher quality with reduced cycle time to meet global competition. The skills and competencies required of IS professionals to successfully operate as change agents in these environments are constantly expanding. This paper presented the foundations of this environment and the results of a survey of IS professionals operating in this environment. The survey results indicate that IS professionals believe the identified areas to be important (table 2) but also believe that their own competencies in many of these areas are relatively low (table 1). The implications of these results for organizational management are significant. IS professionals are aware of their changing and complex environment and of the new demands to adopt change agent roles that are being placed upon them. They are also aware that their current competency levels need to be improved. Organizational management can use the results of this survey as guidelines to implement improvement programs to enhance the competency levels of their IS professionals.

References

References available from first author upon request (mcguire@american.edu).