A DYNAMIC MODEL OF GROUP LEARNING AND EFFECTIVENESS

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ABSTRACT

The objective of this study is to explore factors that influence the quality of group learning and group effectiveness in organizations. Learning enables groups to acquire new skills, improve processes, find new ways of working, and enhance their decision-making process. However, group learning is affected by a set of structural, interpersonal and cognitive factors, which may foster or hinder the engagement of group members in learning-oriented activities. This study regards work groups as complex social systems and suggests that the explanation of the quality of learning and the effectiveness of a group lies in the interrelations of these factors. Existing research on group learning tends to follow an input-process-output approach; in contrast, this study offers a system dynamics model to explore the intricate relationships that arise from the factors such as group dynamics and leader behavior and that influence the outcomes of a work group. Although the model is highly aggregated, the simulation results can improve our understanding of the interrelations of key factors that influence group learning and effectiveness and farther the path for future research using system dynamics to study work groups as complex systems.

Key words: group dynamics, group effectiveness, group learning, leadership, organizational learning, system dynamics.

INTRODUCTION

Researchers have emphasized the value of group learning to help organizations achieve sustained effectiveness (Senge, et al., 1990) and breakthrough innovation (Marsick, Dechant & Kasl, 1993). The performance and effectiveness of groups affect the overall performance and effectiveness of an organization – from top management groups to production groups, all of them contribute to the organization's outcomes. A top management group that learns

continuously is able to evaluate the organization context and develop and communicate strategy and vision more effectively and readily in the face of changing environments. For a product development group, learning can be translated into creative, novel products and solutions to customers. Learning can help production groups to execute and improve manufacturing in such ways as to decrease production errors and to deliver high quality products faster.

Recognizing the relevance of group learning and its influence on organizational learning and effectiveness, this study follows a group-level perspective of learning and effectiveness in organizations. The objective of this study is to explore and understand the complex interdependences and underlying structures at the behavioral and cognitive level, which influence group learning and effectiveness over time. Research on group learning and work group effectiveness has emphasized the importance of structural, cognitive and interpersonal factors. However, most of the studies have addressed these factors separately. Although existing research provides a mixture of assertions about causal relationships, case studies, detailed descriptions of group learning and effectiveness, it does not present a clear, direct statement of dynamic theory. This study seeks to bridge this gap by developing an integrated model, which account for the interactions of these factors and how they foster (or hinder) group learning and effectiveness. In order to do so, this study applies a system dynamics approach, which helps explore complexities and underlying structures that generally are not detected by the input-output type of models generally used in organizational studies.

EXISTING MODELS OF GROUP LEARNING AND GROUP EFFECTIVENESS

Studies of work groups in a variety of organizational settings have revealed that group effectiveness is enabled by structural factors such as group composition, task design, reward systems, and organizational structure (Hackman, 1987). In contrast, studies following the cognitive approach to organizational learning have emphasized cognitive and interpersonal factors, such as shared group beliefs, understandings, and emotional tone, to explain effectiveness (Argyris, 1993). Yet others have provided an integrative approach to group learning and effectiveness in which both structural factors and cognitive structures (socio-psychological traits) have a direct as well as indirect impact on group outcomes (Cohen & Bailey, 1997; Edmondson, 1999).

However, the majority of group effectiveness models do not address the learning process explicitly as a factor that influences effectiveness of work groups. This can occur because of the array of definitions of learning existing in the literature as well as because of the common association of learning with performance (Fiol & Lyles, 1985), in which low performance is generally associated with lack of learning. The relation between learning and performance is more complex than it has been supposed. Group learning can occur without observable changes in group performance, or group performance can increase due to factors in the context of the organization (structure, strategy) or of the group (composition, norms, objectives), without any learning process occurring.

Some models characterize learning as an outcome, part of group effectiveness and not as a process in itself that influences effectiveness. For example, in the model of group effectiveness offered by Ancona and her colleagues (1996), group learning is the result of group operations, which includes internal group processes and the management of the relations with other groups. The operations of a group are, in turn, influenced by factors such as organizational culture, reward systems, and group design (group composition, nature of the task and structure of the group, including size, roles and objectives). Group learning is measured through the acquisition of new skills, perspectives and behaviors as needed by changing circumstances. A feedback from effectiveness to group operations implies that these two components interact over time, although the model does not explain how they interact.

In contrast to the approach that considers learning as an outcome, the model of group learning proposed by Edmondson (1999), presents learning as a process and shows the behaviors that influence group learning. Edmondson's model consists of three basic elements, which, working together, improve group performance. The three elements of the model are: (1) *antecedent conditions*, in which group structures such as context support (e.g. group and task design, rewards, and information system) and leadership influence the ability of a group to perform effectively; (2) *team beliefs,* which encompass shared mental models that guide or hinder learning behavior, including psychological safety – a shared belief that the group is safe for interpersonal risk taking; and (3) *team learning behavior* – activities carried out by group members through which a group obtains and processes data that allow it to adapt and improve. Examples of learning behavior include seeking feedback, sharing information, asking for help, talking about errors, and experimenting with new ideas and processes. It is through these activities that groups can detect changes in the environment,

learn about customers' requirements, improve members' collective understanding of a situation, or discover unexpected consequences of their previous actions.

Edmondson's model follows the dominant way of thinking about group learning and effectiveness in groups, which is reflected by input-process-output models (Guzzo & Shea, 1992). In this type of model, input generally refers to organizational context and group characteristics; processes refer to the interactions among group members, including exchange of information, influence attempts, and leadership efforts, while output is the results yielded by the group, such as ideas, decisions, performance, and effectiveness. This type of model is useful to organize our thinking about how groups operate in organizations (Hackman, 1987; McGrath, 1986), although it does not explicitly shows the interrelations of the various variables that influence group learning and effectiveness.

A SYSTEMIC APPROACH TO GROUP LEARNING AND EFFECTIVENESS

This study considers learning as a process and group as a complex social system and, using a system dynamics approach, it seeks to integrate structural, cognitive and interpersonal factors in order to better understand how these factors, together, influence the quality of learning and the level of effectiveness in work groups. A system dynamic model, which captures the evolving behavior of interrelated variables, is a useful tool for exploring theories of group learning and effectiveness. A system dynamic model highlights causal relationships, or feedback processes, in which variables influence, and in turn respond to one another. Feedback processes are central to social systems, and hence to the study of groups and organizations. As Weick argues:

> "The cause and effect relationships that exist in organizations are dense and often circular. Sometimes these causal circuits cancel the influences of one variable on another, and sometimes they amplify the effects of one variable on another. It is the network of these causal relationships that account for much of what happens in organizations. Though not directly visible, the causal patterns account for more of what happens in organizations than do some of the more visible elements such as machinery, time clocks, and pollution equipment" (Weick, 1979, p.7).

The Group Learning-Performance Process

Although the literature presents a variety of definitions and explanations for group learning, this study focuses on group learning as an ongoing process of reflection and action based on shared understanding and grounded on experience. For group learning to occur, group members need to engage in learning oriented-activities such as reflective conversation,

experimentation, feedback seeking, and discussions of errors or unexpected outcomes. Through such behaviors, learning is enacted at the group level (Edmondson, 1999).

Frequent engagement in learning-oriented activities benefits the group by increasing its aggregated capacity to produce superior results. For example, productive discussion of errors helps group members uncover sources of inefficiency; feedback seeking helps them understand customers and coordinate their tasks more effectively; and experimentation provides the group with the grounds to design new solutions, implement new features, and correct errors and mistakes. As group members learn and experience improvement, their enthusiasm and willingness to commit themselves to the learning initiatives increase naturally (Senge et al., 1999). The benefits that learning provides constitute a source of satisfaction (Costa, 2000) and reinforcing commitment to the group objectives, leading group members to strengthen their investment in learning-oriented activities. Loop R1 – *engagement in learning* – in Figure 1 shows such dynamics: an increase of the group's engagement in learning-oriented activities will lead to an increase in group performance, which in turn will enhance group satisfaction with its achievements; the positive results of group learning efforts will increase the group willingness to invest in learning, then closing the reinforcing loop R1.

The balancing loop B1 – *performance by improvement* – in Figure 1 suggests that an increase in the group performance may reduce the perceived need of the group to improve or change, creating the sense that the engagement in learning-oriented activities is no longer necessary. The difference between the actual performance (represented by the variable group performance) and the performance goal generates a gap that allows the group to assess its need to improve or change in order to reach its goals. Therefore, as group performance rises, the performance gap tends to decrease given that performance goal (the objective of the group) is exogenous and does not change along the project execution, leading to a decrease in the engagement of the group in learning-oriented activities. The benefits created by such learning activities thus decline, leading eventually to inferior results or at least to stagnation. But, once the group performance decreases, the performance gap will increase, making the system work in an opposite direction in an attempt to restore or improve the group performance.

Such structure (the combination of loops R1 and B1) forms the basis of a group's process of detecting and correcting errors or adjusting its course of actions. For example, a group in the development phase of a new product can compare data from its progress with data gathered from stakeholders (e.g. managers, clients, other groups). If the data show any

inconsistencies, the group can engage in learning-oriented activities such as experimentation with new ideas or feedback (or help) seeking in order to implement timely changes in the design, features and other aspects of the product.

However, the persistence of a considerable performance gap might lead the group to focus its effort on routine tasks in order to increase the group performance. This kind of increase in performance is considered a first-order improvement (Repenning & Sterman, 2002), that is, by directing their efforts to complete routine tasks, group members can increase their productivity, and hence their performance, but at the cost of learning and long-term effectiveness. Such dynamics are represented by the balancing loop B2 – *performance by routine* – in Figure 1.

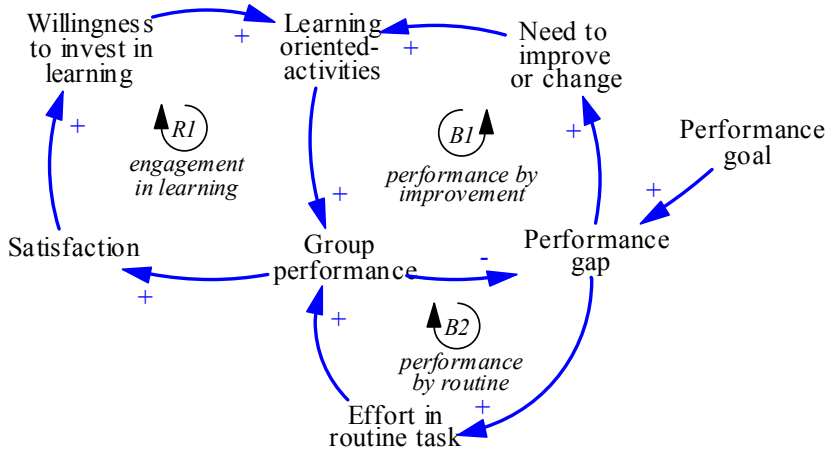


Figure 1: High Level View of the Causal Learning-Performance Process

The Role of Socio-Psychological Factors

In order to collectively learn, group members have to suspend their individual assumptions, go beyond personal defensiveness, and present ideas openly (Senge, 1990). For individuals to participate in learning-oriented activities, they need to feel safe and confident and expect that they will not be exposed to situations that threaten their self-esteem (Argyris & Schön, 1974). Group members need to perceive the possibility of analyzing data on group performance, seeking feedback, and discussing mistakes without losing their identity or integrity, thereby allowing them to admit disconfirming data rather than denying it (Schein, 1992).

The enthusiasm or apathy of a group in dedicating itself to learning-oriented activities is positively related to the perception of group members in regard to power and influence and to interpersonal risk present in the group atmosphere. This perception is represented in the causal loop diagram (Figure 2) by the variable psychological safety, which offers support to group members to overcome the defensiveness that arises when they face difficult situations or when they are presented with data that disconfirm their expectations. Therefore, the higher the level of psychological safety, the more secure group members feel, and the more willing they become to invest in learning. As group members increasingly engage in learning behaviors, they interact and collaborate more, leading to group internal processes improvement. With better internal processes, group members often experience a rise in openness and trust, promoting the development of trusting interpersonal relations, which include productive communication, collaboration and cohesiveness (McGrath, 1984). As group members develop better interpersonal relations they tend to cohere more and develop a sense of safety (Kahn, 1990), increasing the level of psychological safety of the group. Such dynamics are represented by the reinforcing loop R2 – *group processes* – in Figure 2.

The level of psychological safety in the group is also affected by the behavior of the group leader. A group leader, who is available to discuss ideas and help group members, provides constructive feedback, and is open to inputs and suggestions, tends to foster an atmosphere of trust and safety. However, a leader, who acts in autocratic or punitive ways, tends to create an atmosphere in which group members will be reluctant to face the interpersonal risk involved in such learning-oriented activities as discussing errors and seeking feedback or help. As the performance of the group suffers, the performance gap increases, indicating a perceived need for leader coaching. A supportive leader, therefore, increases his or her attention to the group, coaches group members, and/or provides information and training necessary for the completion of the tasks. Once the leader contributes to creating a safe and trustful environment, the level of psychological safety in the group increases and members will become more confident to engage in reflective conversation, experiment with new ideas and look for better ways to work together, hence improving group overall performance and effectiveness, as represented by the balancing loop B3 – *leader influence* – in Figure 2.

An increase in group performance generally brings about in members a sense of satisfaction in relation to the group outcomes and situation (Costa, 2000). This satisfaction can lead to a higher commitment of members to the learning initiatives, which reinforces,

even more, the outcomes of the group. On the other hand, when the group is too much satisfied with its performance and situation, a limiting process can arise in the system. Group members may feel satisfied with their accomplishments and starts showing a higher level of complacency and little willingness to invite discussion of opposing ideas or to tolerate disagreement in opinions, especially from outsiders. Consequently, the level of tolerance of dissension in the group decreases and some group members may feel that they do not have room to expose their ideas any longer, a perception that will negatively affect the level of psychological safety in the group (Edmondson, 1999). A lower level of psychological safety will directly affect the willingness of group members to engage in reflective conversation and discussions of errors as well as in other learning-oriented activities, leading to a decrease in group performance, as suggested by the balancing loop B4 – *group complacency* – in Figure 2.

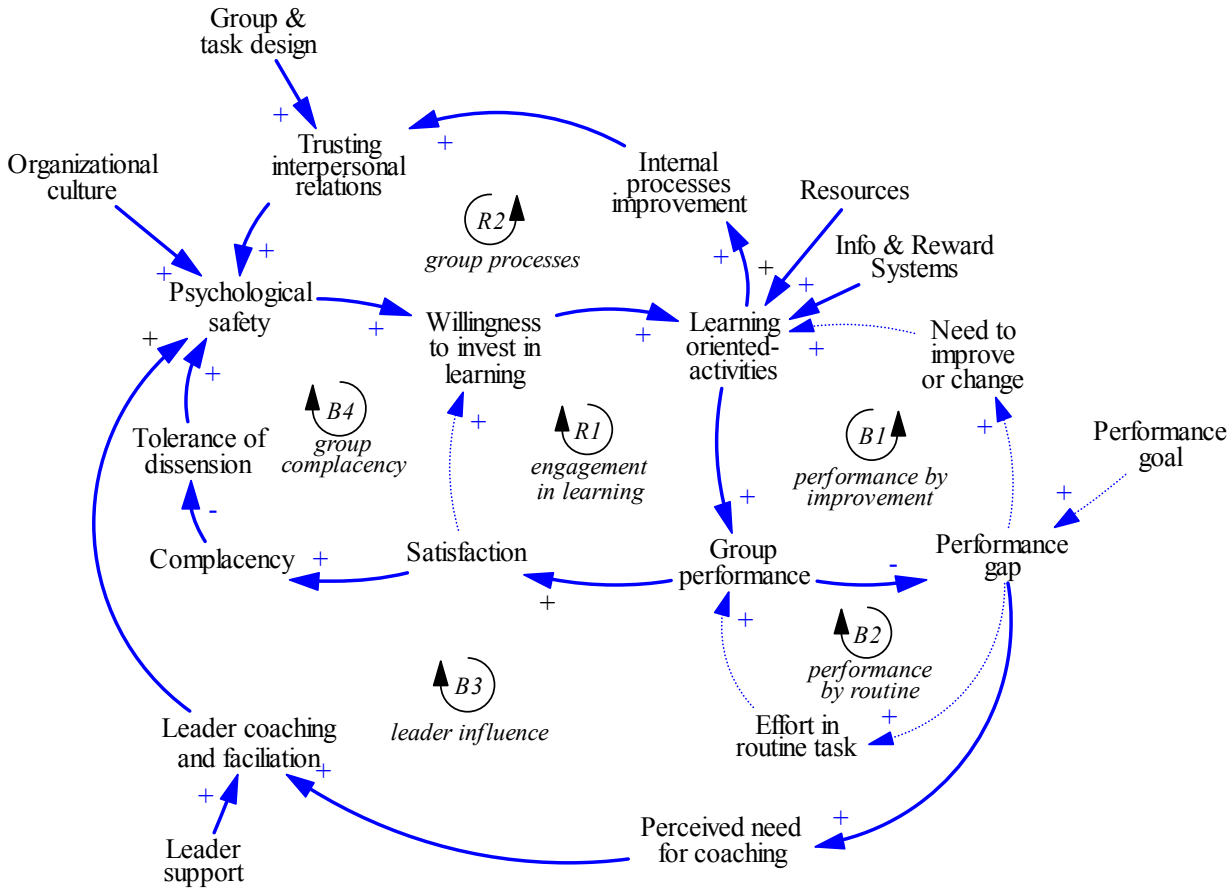


Figure 2: High Level View of the Influence of Socio-Psychological Factors
Doted lines convey loops represented in the previous section of this paper.

Structural Factors: Organizational Context, Group Design and Task Design

The literature on work groups has reported structural, supportive conditions that contribute to group learning and effectiveness (Edmondson, 1999). Organizational context, group design and task design are considered structural factors that influence a group's ability to work effectively (Hackman, 1987), and therefore, they are accounted for in the group learning model.

Organizational context refers to factors such as organizational culture, rewards system, information systems and resources. The culture of an organization is both the consequence of the organization's prior experience and learning, and the basis for its continuous capacity to learn (Schein, 1992). What the organization can, or cannot, do will depend very much on the actual content of its culture and how that culture aligns or integrates the various sub-cultures of its sub-systems (e.g. business units, functions, and groups). A culture that emphasizes cooperation, mutual responsibility, and the exchange of information sets the ground for teamwork. Likewise, a reward system that values collaboration fosters the motivation of group members to collaborate and communicate, as oppose to a reward system that values individual achievement (competition). Information systems are important in providing groups with access to relevant information for the completion of their tasks. The availability of resources, such as equipment, the necessary technology for carrying out the work, and time slack, among others, allows groups to complete their tasks effectively and to engage in learning-oriented activities. A lack of time, for instance, limits the group's ability to experiment, seek feedback, and reflect on results.

Group design refers to the composition of the group (skills, backgrounds, experiences and personality of group members) and to group structure (relative size, formal role of each member, clear goals, and group norms – or expectations about how to behave). These factors of group design were found to be relevant to a group's ability to work together (Hackman, 1987; McGrath, 1984) and to engage in learning behaviors (Edmondson, 1999). For instance, adequate skills and experiences are found to have a positive effect on performance, especially when tasks assigned to the group are diverse and require a wide range of competences. Relative size is another relevant aspect of group design. Campion, Medsker and Higgs (1993) assert that groups need to be large enough to accomplish their assigned work, but when too large, groups may become dysfunctional because of increased need for coordination or reduced involvement of members. Clear, well-defined group goals, aligned with members' individual work goals, promote commitment and foster morale in the group.

Task design refers to the way in which the work is organized and distributed among members; it includes aspects such as autonomy and interdependence. Recent studies indicate that autonomy improves worker attitudes, behaviors and performance (Cohen & Bailey, 1997) and that task interdependence requires members to work together to complete significant tasks (Wageman,1997).

These structural factors are represented in the dynamic model in Figure 2 and are treated as exogenous variables because groups generally have no direct control over such factors.

The Simulation Model

To explore how the structural, interpersonal and cognitive factors discussed earlier influence group learning and effectiveness, a simulation model is constructed in this section. The simulation model builds upon the causal diagrams developed previously (shown in Figures 1 and 2) and seeks to investigate the following premise: while some work groups present a high level of learning and effectiveness and can work with limitations and correct their course or situation, others present a low level of learning and effectiveness, which tend to perpetuate. This study argues that effective groups, which usually present a high level of psychological safety (or a lower aggregate level of perceived power and interpersonal risk) tend to engage more frequently in learning-oriented activities than those that present a lower level of psychological safety (or a higher aggregate level of perceived power and interpersonal risk). Figure 3 shows the reference mode that depicts this phenomenon referred to elsewhere as "asymmetrical phenomenon" (Lizeo, 2004). Although the performance of effective groups may present an oscillatory pattern over time, it tends to maintain at a higher level because such groups are more likely to engage in learning-oriented activities, detect errors and take the necessary actions to complete their tasks or projects, achieving their performance goals. Conversely, the performance level of non-effective groups is likely to decline over time due to infrequent engagement of group members in learning-oriented activities, undetected errors and individual perceptions that lead to self-protection and reluctance to take interpersonal risk, compromising group effectiveness and goal achievement.

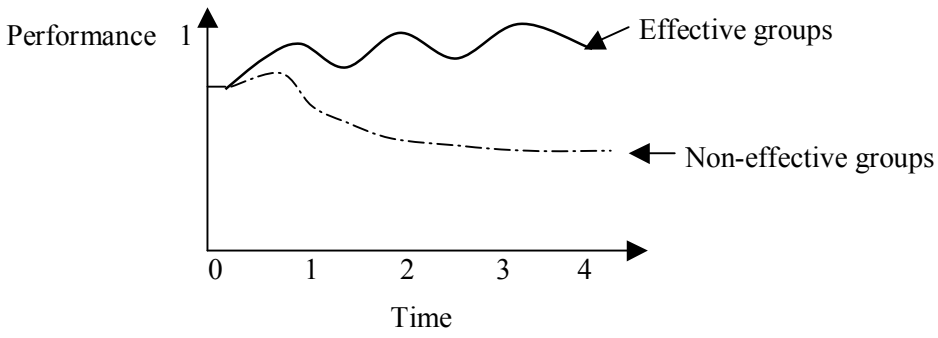


Figure 3: Group Effectiveness (Performance) over Time

Model Structure

Despite the apparent oversimplification of the model shown in Figure 4, its variables can capture the causal roles of relevant theory and constructs. The model essentially captures into a stock and flow diagram the causal loops represented in the previous sections, maintaining the correspondent names of each loop. Most of the variables presented in the causal loop diagram (Figure 2) are also represented in the simulation model. While some variables and loops were expanded in order to better capture the dynamics of the system, others were aggregated because they presented relatively similar dynamics and/or patterns of behaviors. For example, in loop R2 – *group process* – the variables international processes improvement and trusting interpersonal relations were collapsed into the variable group process improvement. Normal level of collaboration reflects the level of group collaboration required of groups to work collaboratively.

Although learning-oriented activities encompass various activities such as feedback seeking, discussion of errors and mistakes and experimentation, the model depicts these activities as an aggregate variable, which captures the basic influence on group performance.

The model also highlights how the level of psychological safety is built within a group and how it affects the engagement of the group in learning-oriented activities. Psychological safety, conceptualized as the shared belief that the group atmosphere is safe for interpersonal risk-taking, is determined by the effect of the group interpersonal relations,

the influence of the leader (group leader coaching), the level of tolerance of dissension, and the organizational context, represented in the model by the variable normal level of psychological safety.

Group performance is captured by a mechanism that comprises group productivity and tasks completion, including tasks rework, which is represented by the variable fraction of rework.

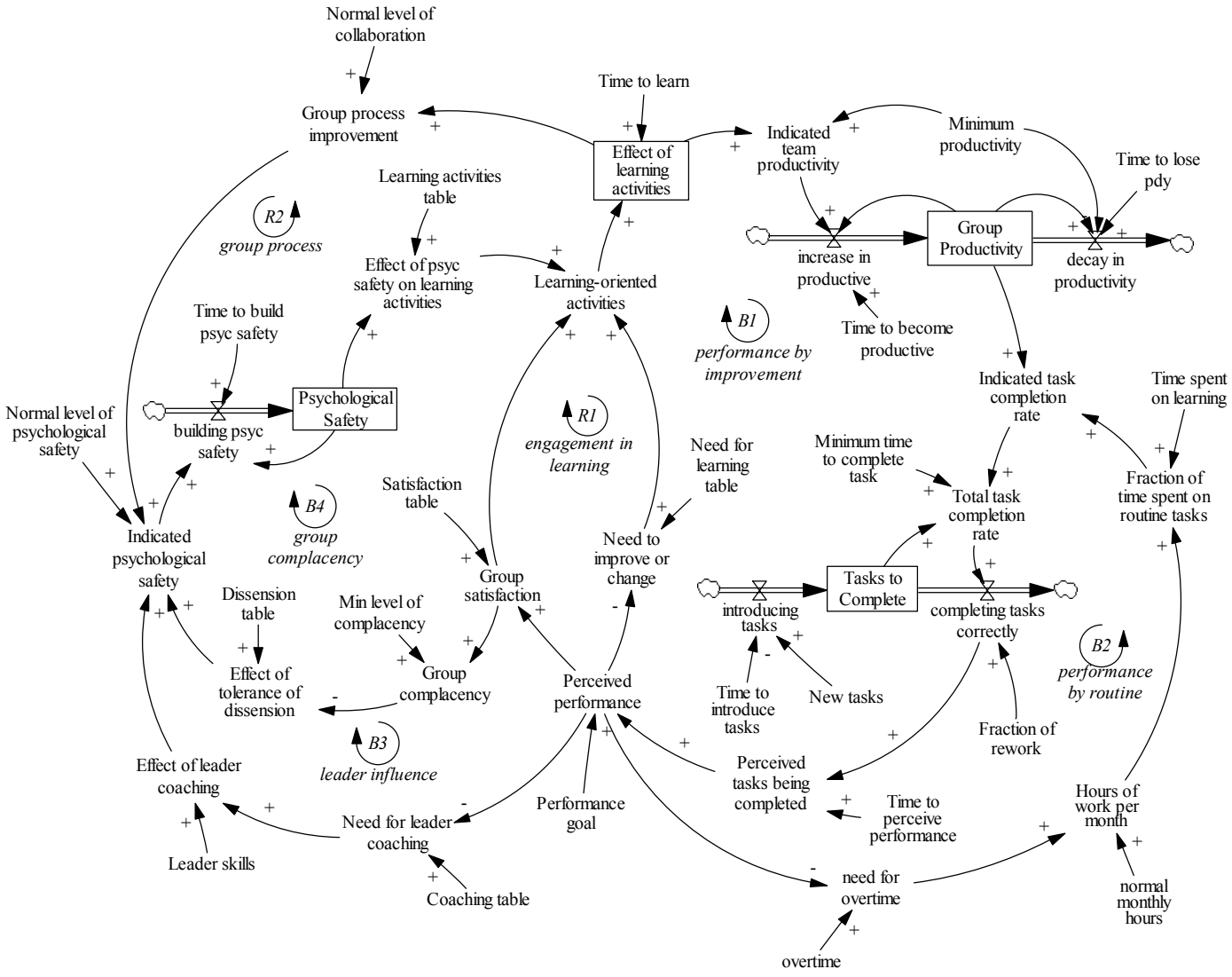


Figure 4: A Simulation Model of Group Learning and Effectiveness

Simulation Runs

The first set of simulation runs is a base case. The base case simulates a scenario in which the organization provides the necessary resources, information and rewards for groups to perform their tasks and achieve their pre-established goals. The group and tasks were designed to foster interdependence (represented by group process improvement = 0.7), the group leader is fairly supportive (capture by leaders skills = 0.7), and the organizational context provides the minimum conditions for learning activities to take place (normal level of psychological safety = 0.7). The initial level of psychological safety is set at 0.5, indicating that group members start out working together with some level of comfort. The scale ranges from 0 to 1.

Performance goal is set at 1 task/month, as it is minimum productivity. Fraction of rework is expected to be 10% of tasks completed. The results of the base run in show in Figure 5.

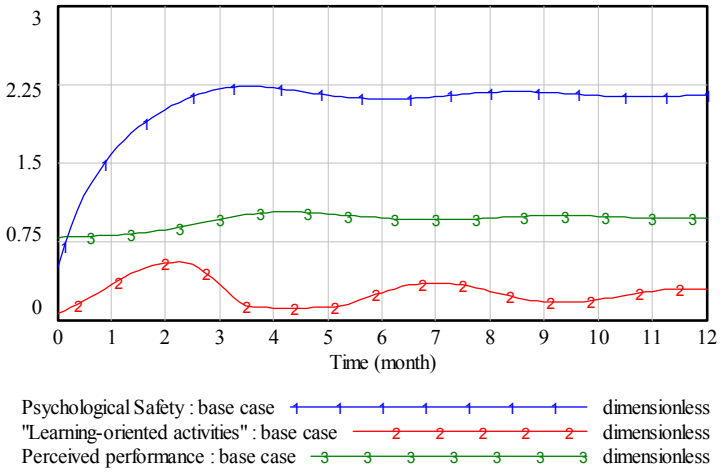


Figure 5: The Base Case Run[1]

The results of the base run suggest that group members engage in more learning-oriented activities once their level of psychological safety increases. The overall outcome is an increase in group performance. As group performance increases, group members direct less effort to learning-oriented activities, resulting in a slight decrease in group perceived performance (shown at time = 5, in Figure 5). As group performance decreases, group members tend to increase their engagement in learning-oriented activities.

[1] The model begins in equilibrium.

The Effects of Socio-Psychological Factors on Group Learning and Performance

The next set of simulations use two hypothetical groups: the High-Level (or Group H), representing a high-learning, highly effective group; and the Low-Level (or Group L), representing a low-learning, non-effective group. It is assumed that both groups share the same structural characteristics regarding group type (product development groups), size (six members and a leader), and design (group members come from different functional areas and complement one another background necessary for the completion of the tasks). The groups also share the same organizational context (a large manufacturing company), which fosters innovation and rewards collaboration, and face the same environmental factors, in which recent changes in the industry can threaten the leadership position of the organization. The goal of the groups is to develop new products to enhance an existing product line. The tasks present a considerable level of interdependence and, therefore, require group members to work together and collaborate.

The High-Level and the Low-Level groups, however, present the following contrasting characteristics, shown in Table 1.

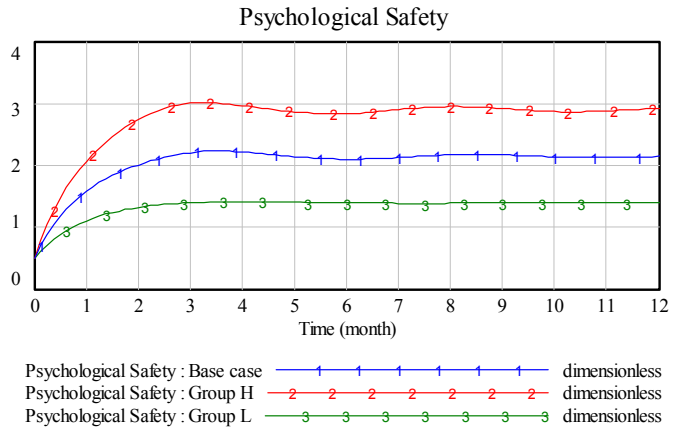
Group High-Level (H)	Group Low-Level (L)
• low level of perceived power and interpersonal risk (high level of psychological safety)	• high level of perceived power and interpersonal risk (low level of psychological safety)
• a leader who encourages input and productive discussion	• a leader with autocratic style, who tends to control the discussions
• an atmosphere characterized by enthusiasm and confidence	• an atmosphere characterized by event explanation (attributions to people and to their notions and points of view)
• openness to communicate ideas and seek feedback	• reluctance to discuss errors and seek feedback

Table 1: Contrasting Characteristics of a High-Learning and a Low-Learning Group

The next runs contrast the two groups described above – Group H and Group L – with the base case. The characteristics of the groups shown in Table 1 are simulated in the model by changing the following parameters:

Run	Leader skills	Level of group collaboration
Base	0.7	0.7
Group H	1	1
Group L	0.4	0.4

Figures 6a, 6b and 6c show the results of this run for group psychological safety, group perceived performance and group engagement in learning-oriented activities, respectively. Both groups start with the same initial and normal levels of psychological safety (initial level = 0.5; normal level = 0.7), but Group H builds up its level of psychological safety faster given the higher level of group collaboration and the positive influence of its leader. The higher the level of psychological safety experienced by the group, the more comfortably group members are to engage in learning activities, and the earlier the results will appear because group members can respond to changes and correct their course of action more promptly, reestablishing an adequate level of performance.



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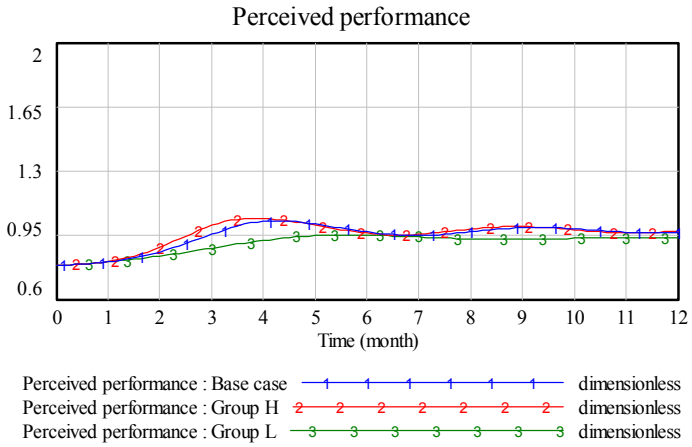

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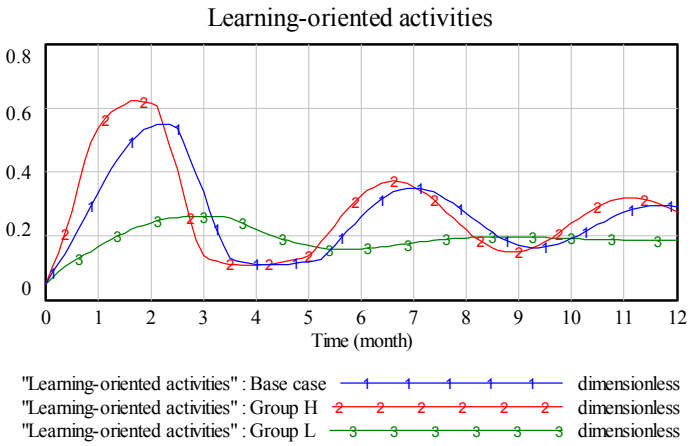


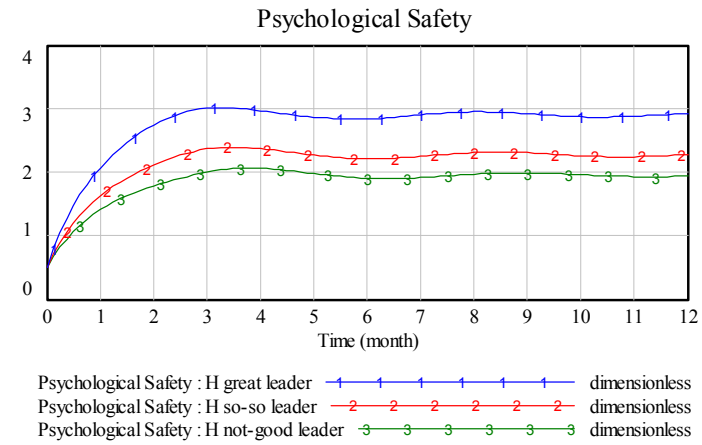
(6c)

Figure 6 a, b & c: Effects of Socio-psychological Factors on Group Performance

Figure 6c shows that the engagement of Group H in learning activities oscillates more than the engagement of the other groups. The group engagement in learning oriented-activities is considerably higher at the beginning of the project and adjusts downwards as group members learn and gain experience with their tasks. However, Group H members are able to respond to decreases in the group performance level more quickly than the base case group.

Group Atmosphere and Leader Influence

The atmosphere of a group helps determine the group internal processes and influence the ability of the group to survive in, and adapt to, the external environment (Schein, 1999). Past research shows that the leader of a group influences the atmosphere of the group in ways that can promote or hinder the building of psychological safety in the group. To test such prediction the variable leader skills was varied between 0 and 1 for both groups H and L.



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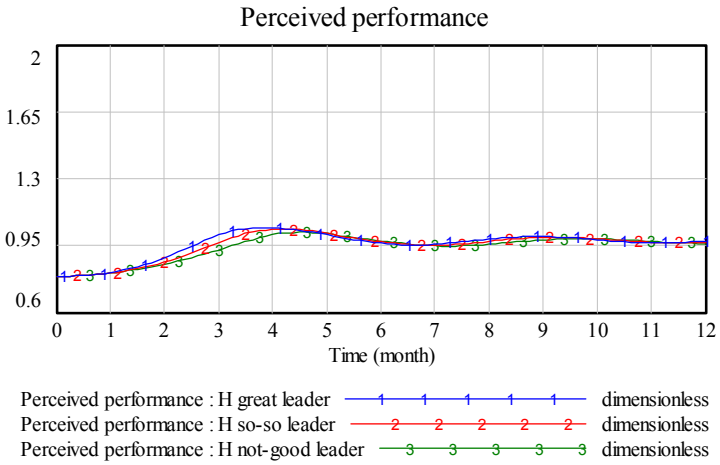

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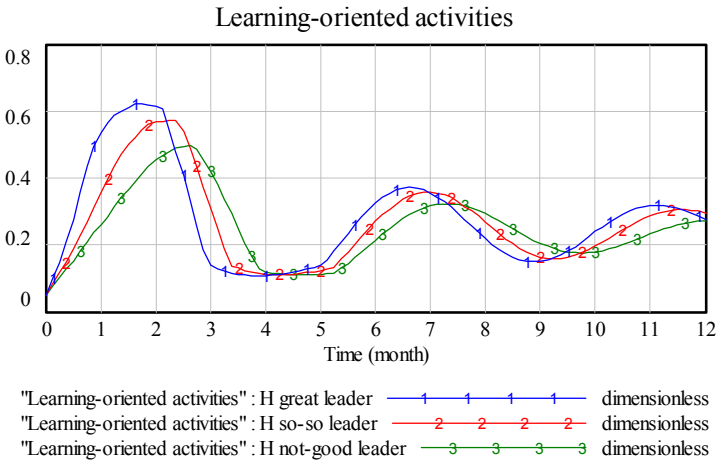
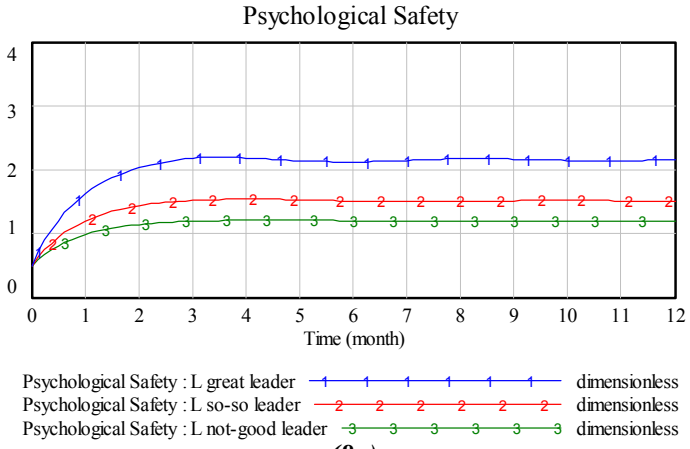


(7c)

Figure 7 a, b & c: Effect of Leader Influence on High Learning Group

The results of this simulation shown in Figure 7a corroborate the theory that the leader influences the group atmosphere, and Figure 7c shows that group members become more willing to engage in learning activities, which happens earlier in the lifecycle of the group project. The influence of the leader has little than expected impact on group performance (Figure 7b), however. Such little impact may be connected to the fact that Group H members have created trustful interrelationships and a relatively high level of psychological safety, which help mitigate the effects of bad leadership.

The impact of leadership becomes more apparent when the group presents a lower level of group collaboration and a less safe atmosphere. The group engagement in learning activities and hence group performance benefit from a more supportive and responsive leader as shown in Figure 8.



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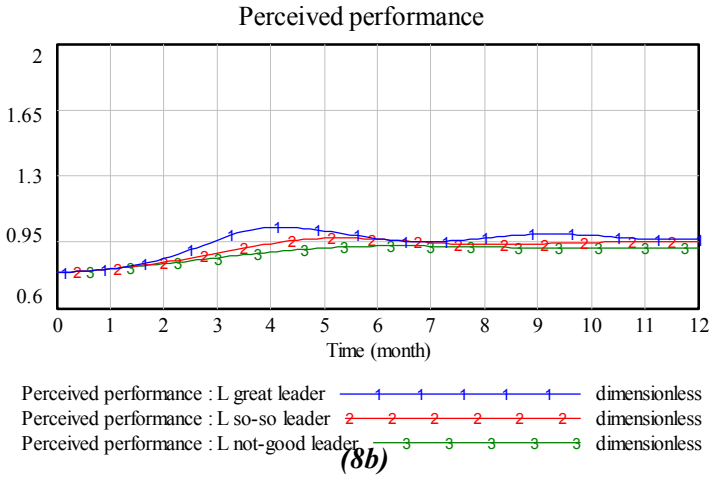

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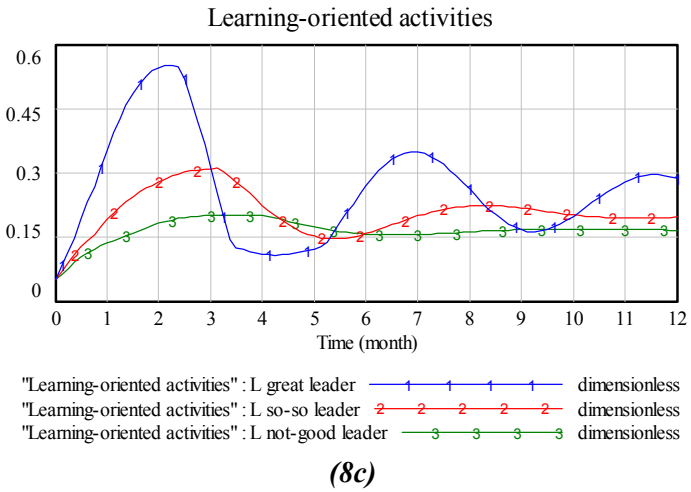

(8c)

Figure 8 a, b & c: Effect of Leader Influence on Low Learning Group

The results of the simulation runs presented in Figures 7 and 8 suggest that more emphasis should be given to preparing group members to work interdependently and proactively and that the role of the leader should be one of a facilitator, helping group members grow and develop, challenging them whenever necessary, and supporting them through difficult situations.

DISCUSSION

This study considered work groups as complex social systems and applied a system dynamics approach to group learning, contrary to a linear, mono-causal perspective mostly used in organizational studies. The dynamic model of group learning and effectiveness offers a useful framework to think about the complexities of group learning process. The application of the model allows the interpretation of dominant dynamics in the functioning of a particular group and the identification of sources of ineffectiveness and leverages for the quality of learning and effectiveness of work groups. However, the identification of the sources of ineffectiveness and the need to change does not guarantee that the changes can be implemented without difficulties. This reinforces the importance of analyzing the group as an intact social system, identifying in its functioning areas of opportunities for viable and realistic changes.

In addition to confirming some of the findings in previous research (cf. Cohen & Bailey, 1997; Edmondson, 1999), the dynamic model extended existing theories and frameworks and provided new insights into group learning and effectiveness. The

simulations highlighted the importance of leader influence (supportive and responsive behavior) and trustful interpersonal relations as some of the factors that influence the level of psychological safety in a group, which in turn, influences the group atmosphere and the extent to which group members engage in learning-oriented activities. The interdependencies of these factors can cause variations in the level of learning among groups in organizations, since they can inhibit learning at the organizational level and hinder the organization capacity to innovate and deal with changing environments. Work groups change for multiple reasons leading to changes in its functioning, making some dynamics not previously showed by the group arise. Moreover, socio-psychological forces that act in individuals and groups can function as potential obstacles in the transition from the necessity of change to the occurrence of the demanded change.

However, the simulation model offered in this paper has limitations and can be enhanced in several ways. First, the variable "learning activities" can be decomposed and represented in greater detail to capture the multifaceted dimensions of the various activities that contribute to group learning such as feedback seeking and discussion of errors and mistakes. Second, the variable "group interpersonal relations" can be refined to consider the emergence of power and influence in the group.

The theory of group learning deals with individual mental models, beliefs, and anxieties, leading to a quite abstract model with constants and variables difficult to measure or quantify. This study can be carried forward through empirical research, which will provide real data to calibrate the model. Empirical data would enable the optimization of the model and could provide better insights into group learning and effectiveness and hence organizational learning and effectiveness. Moreover, an empirical study would allow the observation of groups in their context and the identification of other factors, such as the role of diversity, preconceptions, and pressure for conformity.

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APPENDIX

(01) building psyc safety=
(Indicated psychological safety-Psychological Safety)/Time to build psyc safety
Units: dimensionless/month

(02) Coaching table
([(0,0)-(2,1)],(0,0.8),(0.1,0.8),(0.2,0.75),(0.3,0.65),(0.6,0.35),(0.75,0.3),
(0.85,0.275),(1,0.25),(2,0.25))
Units: dimensionless

(03) completing tasks correctly=
Total task completion rate*(1-Fraction of rework)
Units: tasks/month

(04) decay in productivity=
(Group Productivity-Minimum productivity)/Time to lose pdy
Units: tasks/(month*month)

(05) Dissension table
([(0,0)-(1,1)],(0,0.0657895),(0.116208,0.105263),(0.247706,0.188596),(0.345566
,0.289474),(0.5,0.5),(0.6,0.625),(0.730887,0.767544),(0.801223,0.824561),
(0.914373,0.890351),(0.990826,0.916667))
Units: dimensionless

(06) Effect of leader coaching=
(1+Need for leader coaching)*Leader skills
Units: dimensionless

(07) Effect of learning activities=
SMOOTH("Learning-oriented activities",Time to learn)
Units: dimensionless

(08) Effect of psyc safety on learning activities=
Learning activities table(Psychological Safety)
Units: dimensionless

(09) Effect of tolerance of dissension=
Dissension table(Group complacency)
Units: dimensionless

(10) FINAL TIME = 12
Units: month
The final time for the simulation.

(11) Fraction of rework=
0.1
Units: fraction

(12) Fraction of time spent on routine tasks=
Time spent on learning/Hours of work per month
Units: fraction

(13) Group complacency=
Min level of complacency*(1+Group satisfaction)
Units: dimensionless

(14) Group process improvement=
Normal level of collaboration*(1+Effect of learning activities)
Units: dimensionless

(15) Group Productivity= INTEG
(increase in productive-decay in productivity,Minimum productivity)
Units: tasks/month

(16) Group satisfaction=
Satisfaction table(Perceived performance)
Units: dimensionless

(17) Hours of work per month= ACTIVE INITIAL
(normal monthly hours+need for overtime,normal monthly hours)
Units: hours/month

(18) increase in productive=
(Indicated team productivity-Group Productivity)/Time to become productive
Units: tasks/month/month

(19) Indicated psychological safety=
Normal level of psychological safety+Group process improvement+Effect of leader coaching-Effect of tolerance of dissension
Units: dimensionless

(20) Indicated task completion rate=
Group Productivity*(1-Fraction of time spent on routine tasks)
Units: tasks/month

(21) Indicated team productivity=
Minimum productivity*(1+Effect of learning activities)
Units: tasks/month

(22) Initial level of Psyc Safety=
0.5
Units: dimensionless

(23) INITIAL TIME = 0
Units: month
The initial time for the simulation.

(24) introducing tasks=
New tasks/Time to introduce tasks
Units: tasks/month

(25) Leader skills=
0.7
Units: dimensionless

(26) Learning activities table
([(0,0)-(4,1)],(0,0.0131579),(0.207951,0.0263158),(0.550459,0.0964912),(1.07645
,0.254386),(1.45566,0.451754),(1.70031,0.644737),(1.88379,0.789474),(2.05505
,0.881579),(2.29969,0.95614),(2.72783,0.995614))
Units: dimensionless

(27) "Learning-oriented activities"=
Effect of psyc safety on learning activities*Group satisfaction*Need to improve or change
Units: dimensionless

(28) Min level of complacency=
0.3
Units: dimensionless

(29) Minimum productivity=
1
Units: tasks/month

(30) Minimum time to complete task=
1
Units: month

(31) Need for leader coaching=
Coaching table(Perceived performance)
Units: dimensionless

(32) Need for learning table
([(0,0)-(2,1)],(0,1),(0.5,1),(0.7,0.95),(0.8,0.85),(0.9,0.7),(1,0.15),(1.07034
,0.085),(1.3,0.05),(2,0.05))
Units: dimensionless

(33) need for overtime=
IF THEN ELSE(Perceived performance<1, overtime, 0)
Units: hours/month

(34) Need to improve or change=
Need for learning table(Perceived performance)
Units: dimensionless

(35) New tasks=
1
Units: tasks

(36) Normal level of collaboration=
0.7
Units: dimensionless

(37) Normal level of psychological safety=
1
Units: dimensionless

(38) normal monthly hours=
200
Units: hours/month

(39) overtime=
20
Units: hours/month

(40) Perceived performance=
Perceived tasks being completed/Performance goal
Units: dimensionless

(41) Perceived tasks being completed=
SMOOTH(completing tasks correctly, Time to perceive performance)
Units: tasks/month

(42) Performance goal=
1
Units: tasks/month
relates to the desired taks completion rate

(43) Psychological Safety= INTEG
(building psyc safety,Initial level of Psyc Safety)
Units: dimensionless

(44) Satisfaction table
([(0,0)-(2,1)],(0.0122324,0.00877193),(0.12844,0.0307018),(0.238532,0.0745614
),(0.373089,0.157895),(0.544343,0.29386),(0.73,0.548246),(0.850153,0.820175
),(0.93578,0.903509),(1.02141,0.95614),(1.18043,1),(2,1))
Units: dimensionless

(45) SAVEPER =
TIME STEP
Units: month
The frequency with which output is stored.

(46) Tasks to Complete= INTEG
(introducing tasks-completing tasks correctly,1)
Units: tasks

(47) Time spent on learning=
25
Units: hours/month

(48) TIME STEP = 0.125
Units: month
The time step for the simulation.

(49) Time to become productive=
1
Units: month

(50) Time to build psyc safety=
1
Units: month

(51) Time to introduce tasks=
1
Units: month

(52) Time to learn=
1
Units: month

(53) Time to lose pdy=
12
Units: month

(54) Time to perceive performance=
1
Units: month

(55) Total task completion rate=
min(Indicated task completion rate, Tasks to Complete/Minimum time to complete task)
Units: tasks/month