Self-Sustainability of Effective Team Performance in a Collaborative Design Environment

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Abstract
A number of studies have contributed to the design and development of effective collaborative design environments. They have focused on the communication of interrelated team members, the creation of shared understanding and vision, and shared discovery of design solutions. However, only few studies have focused on the design or the development of collaborative design environments that would allow all the members of the design team to plan their processes, enact according to their plan, monitor and influence their performance in following the planned processes, and prevent them from deviating unconsciously from their desired performance. This paper introduces the constructs of a distributed process management environment (DPME) which was designed to stimulate self-sustainability of effective team performance in an collaborative design environment by supporting: (a) the shared creation of a process plan, (b) the enactment of a process according to its plan, (c) the monitoring of the outcome and process of the team, and (d) the control of the team performance. It presents the findings of a study conducted for evaluating the effectiveness of the DPME in meeting the conditions required for collaborative building design.

Keywords
Collaboration, Process Management, Sustaining Effective Team Performance

1 Introduction

The building design practice is comprised of a number of design experts who through sharing their ideas, knowledge, and experience achieve an effective design practice. Collaboration is found to be the most preferred group process for achieving an effective design practice (Gray 1989). Over time, a number of studies and theories have contributed to the design and development of effective collaborative design environments (Bhat et al. 1993; Castle and Pollasis 1999; Dave 1995; Davidson and Campbell 1996; Fenves et al. 1994; Gero 1997; Kalay 1997; Khedro 1993; Knapp and McCall 1996; Maher et al 1993; Saad and Maher 1996). Some of these studies have focused on the communication of interrelated team members, the creation of shared understanding and vision, and shared discovery of design solutions. Prime examples of resulting technologies are the group communication support systems (GCSS) and group information support system (GISS). Some of the proposed models of collaboration enhanced the communication models by allowing teams to create a shared understanding and vision (Kalay 1997; Knapp and McCall 1996). Researchers proposed various methods and techniques for supporting joint discovery and authoring of design solutions (Khedro et al. 1993; Maher et al. 1993). Furthermore, many studies have focused on the shared discovery of the processes that the team opts to follow to arrive at its objectives (Cichocki et al, 1998; Heintz, 1999).

The existing techniques and methods for collaborative building design mainly support the communication of information about design decisions. They allow easy exchange of documents and drawings about a design decision over a shared network. Only recently have there been attempts to support the monitoring and tracking of team processes (e.g. Bentley's Viecon.com, Citadon's ProjectNet) in order to support the management of the design project and the design team. However, they have not focused on the problem regarding the sustainability of effective team performance. Although, there has been research on self-sustaining teams in other disciplines (such as organizational behavior, business management, software design), the concept as it applies to building design practice and collaborative building design environments has not been studied extensively. It would appear that few research has focused on the design or the development of collaborative design environments that would allow all the stakeholders in a design team to plan their processes, enact according to their plan, monitor and influence their performance in following the planned processes, and prevent them from deviating unconsciously from their desired performance (e.g. Heintz 1999).

In due course, the aim of this study is to extend the theories of the collaborative design team from a communicating design team to a self-sustaining design team (Figure 1). It proposes to expand the power and versatility of the existing collaborative design environments by constructing an environment which would support design teams not only in communication of design information but also in monitoring and controlling effective team performance.

2 Self-Sustainability of Effective Team Performance

The theories of collaboration stated that team members are significant contributors, and collaboration is achieved when all members of the team work together like the interacting parts of a system to arrive at a shared goal. According to this conceptualization, collaboration requires:

- Interaction with interdependent units: The continuity of a system requires the interaction of its interdepen-

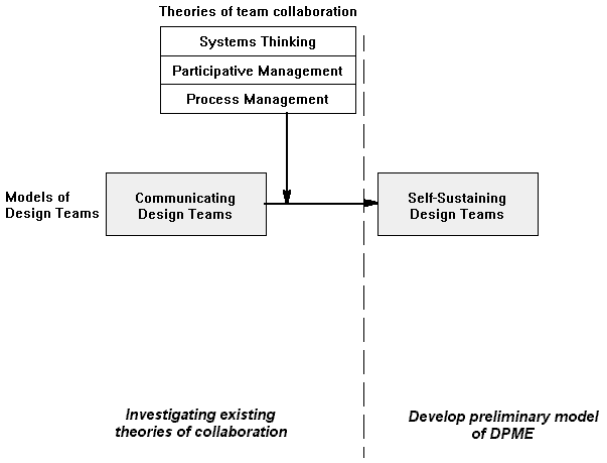

Figure 1. A proposal for expanding the existing the theories of collaborative building design.

dent units (Syer and Connolly 1996; Frey 1999; Gray 1989; Kalay 1997; Schrage 1995)

- Creation of a shared understanding and vision: A system has feedback loops that provide information to system parts (Syer and Connolly 1996; Luthans 1985; Schrage 1995; Senge 1991)
- Exercising of shared creation and discovery: A system goes through a process of transforming input energy to an output (Schrage 1995; Senge 1991; Syer and Connolly 1996)
- Self-sustainability of effective performance: A system monitors and controls its progress and maintains effective performance by continuous feedback (McAfee and Champagne 1987; Schrage 1995; Senge 1991; Syer and Connolly 1996)

Many researchers argue that central to the notion of collaboration is the concept of shared power (Gray 1989; Senge 1991; Schrage 1995). Collaboration urges distribution of power among those whose interests are most keen. In collaboration, the final agreement defining the common good is not the proclamation of a ruling elite or the result of logrolling and majority rule, but rather a consensus agreement among those chiefly involved (Gray 1989). All the stakeholders are encouraged to become involved in problem solving and decision-making. Such a model pictures a self-sustaining team in which all or some of the team members are involved in the monitoring and controlling of the process and the effectiveness of the team performance. In a self-sustaining design team, the team members participate collectively into the planning of the path that the team wants to follow in arriving at its objectives. Continuous feedbacks, either positive or negative, are used as means of orchestrating the joint work and for maintaining the stability of the team.

3 Self-Sustaining Effective Team Performance in a Distributed Process Management Environment

This study started with the basic premise that the effectiveness of collaborative design environments not only hinges upon the communication of information regarding the artifacts that is being designed, but also the control and management of the effectiveness of the team performance.

The researcher developed the conceptual model of a computer-based collaborative design environment, called the *Distributed Process Management Environment* (DPME), to support self-sustainability of effective team performance. DPME is designed to support self-sustainability of effective team performance by enabling the participative management of the process enactment DPME supports the process management model as shown in Figure 2. It allows design teams to (a) discover the path they want to follow to arrive at their objectives or reuse the reference process models that they or others have developed through direct experience (process planning), (b) follow the plan of their processes (process enactment), (c) monitor the performance of the team (process monitoring), and (d) influence the performance of the design team (postmortem).

3.1 Planning of a Design Process

The DPME enables the planning of the process that the team opts to arrive at its objectives. DPME supports an authoritarian management approach by enabling one or some of the team members to plan some or all the design processes. If desired, it also enables the participative management approach by enabling the participation of all members of the team in planning some or all of the design processes. It supports the participative management approach by distributing the authority and responsibility for making or

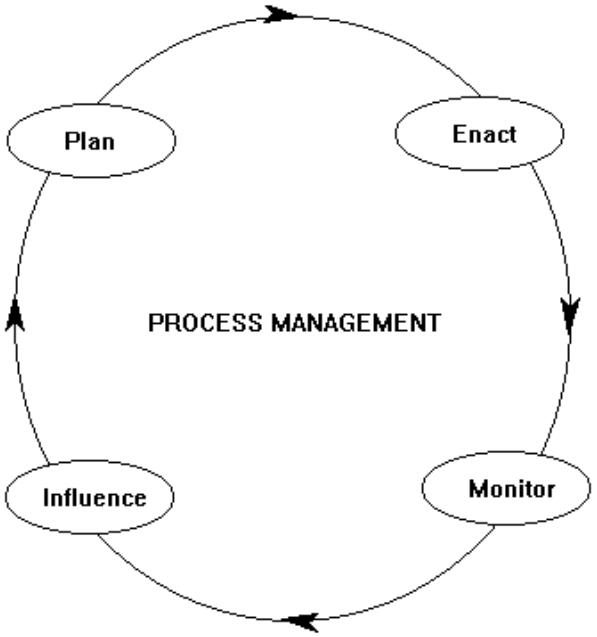

Figure 2. The conceptual model of the process management activity.

influencing the proposals or decisions about a process plan.

DPME allows some or all of the members of the design team to define the plan of a process by enabling them to construct a simplified view of the process, called the *process plan*. The design team creates the process plan by defining (a) the activities in a process (activity-based information), (b) the products required for or produced by the activities (product-based information), (c) resources required for the completion of the activities (resource-based information), (d) the dependencies between the activities, products and resources, and (e) the standards regulating the enactment of the process.

The activity-based information describes the sequential relationship and the dependencies between the activities (Figure 3). It delineates the conditions required for the initiation of the activities. The resource-based information is about (a) participants - which members of the design team are required to participate in the activity, (b) time - how much time is required for its completions, and (c) design knowledge - the various kinds of information that will be required for the completion of an activity (Figure 4 and Figure 5).

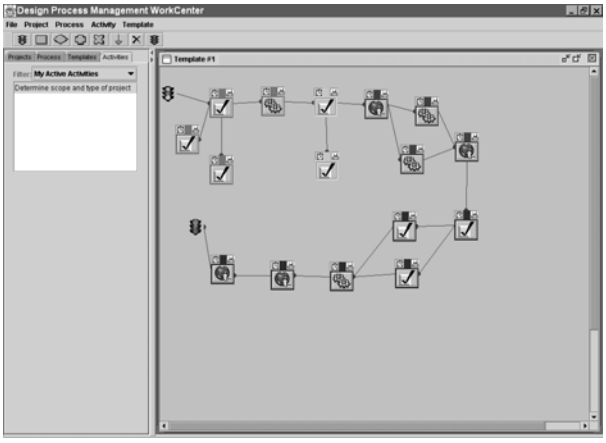

Figure 3. Activity-flow diagram showing the plan of a process.

In the DPME, team members can develop a process plan in two different ways: (a) by creating a new process plan from scratch, and (b) by modifying the template of a process plan

- Creating a new process: A new process definition can be created from scratch by defining the activities and their sequence in an activity-flow diagram. An activity-flow diagram can be created by using the drawing tools as shown in the Process Definition Toolbar (Figure 6). As shown in Figure 7, the user can select an activity from one of the seven phases of building design (pre-constructional phase, schematic design phase, design development phase, construction documents creation phase, bidding phase, construction contract administration phase) and from one of three types of design activities (situation assessment, reactive, and presentation/submission activities). The sequence of the activities can be defined by four flow operators: (a) condition, (b) and, (c) or, and (d) directed Line.
- Modifying template of a process: A design team may have to perform similar tasks, go through similar design processes, and may require similar inputs and resources for similar design projects. The literature consists of a body theories and studies which have identified and delineated the paths that are proven to be reliable for achieving certain objectives and goals of a design team (e.g. AIA's Project Checklist, AIA 1991).

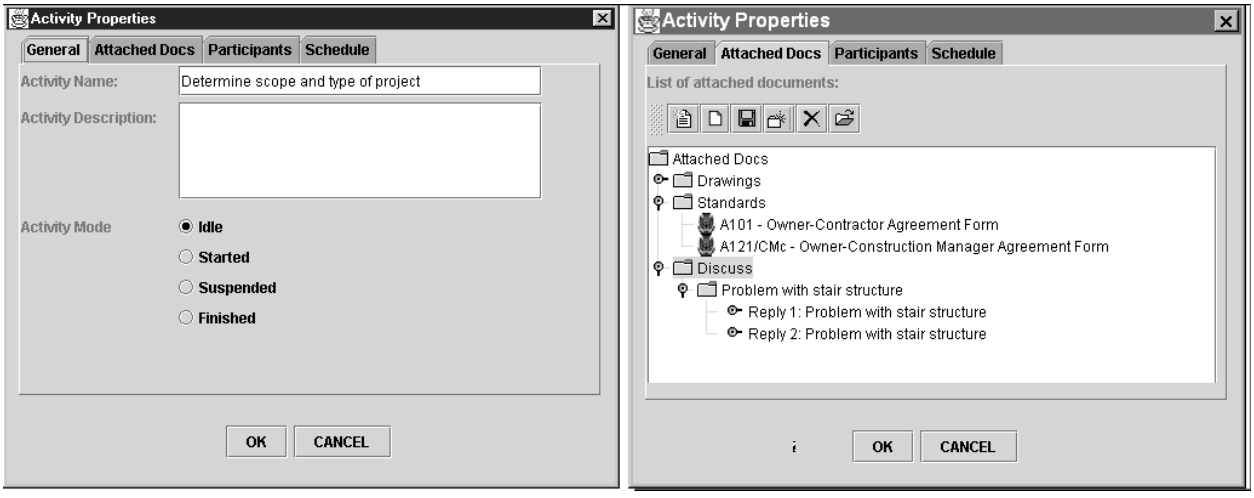

Figure 4. Status and product information about a design activity.

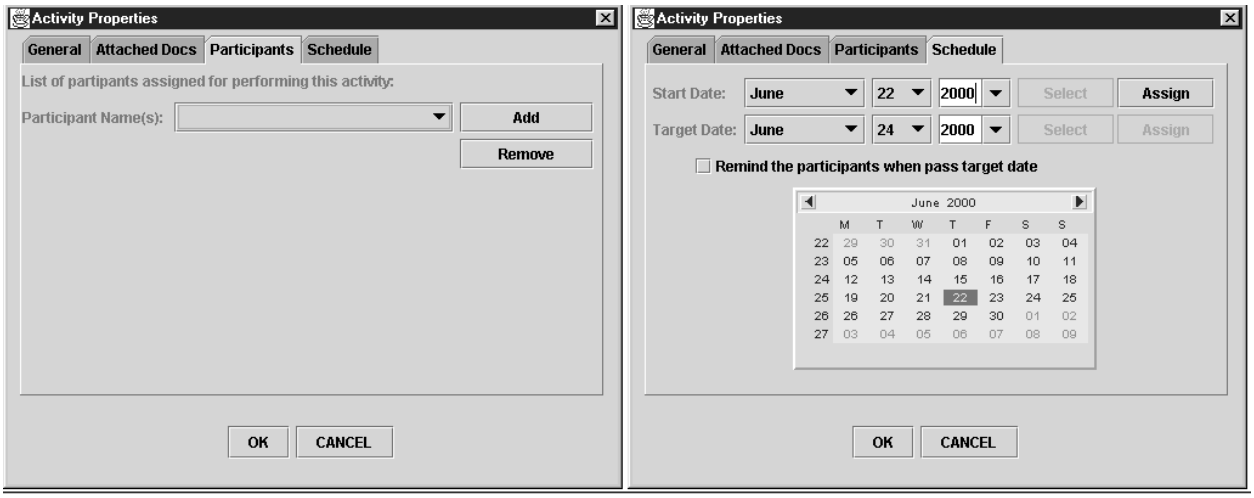

Figure 5. Participants and schedule of a design activity.

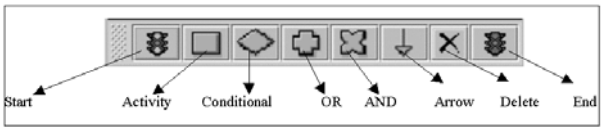

Figure 6. Process definition toolbar.

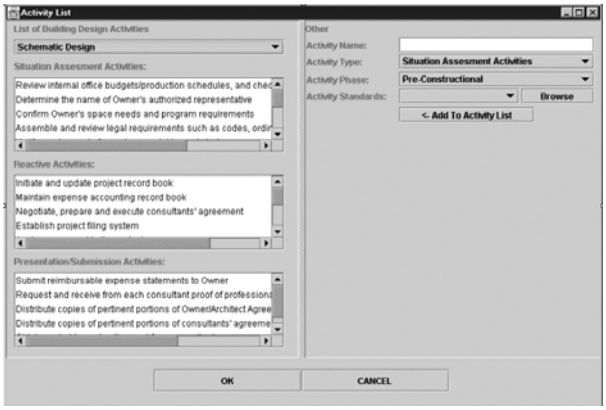

Figure 7. Nature of the activities in a design process.

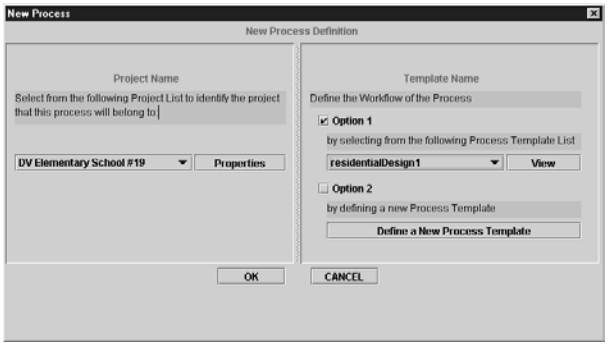

Figure 8. Activation of a process in a design project.

DPME allows design teams to use and reuse the process plans that were proven to be successful in meeting certain objectives and goals of the team. It DPME, the team can construct a reference model, called also the *template process model*, which describes the process that the team plans to follow in similar design projects. A template process model identifies: (a) the activities necessary for the enactment of the process, (b) the products required as inputs or as outputs, (c) the resources necessary for the completion of the activities, and (d) the standards to be satisfied. A user can reuse or edit a template process to develop a new plan of a design process.

3.2 Enacting the Plan of a Design Process

DPME allows design teams to enact according to the plan of the design processes by maintaining the capability to: (a) detect the correlation between the processes being enacted and the plan, (b) identify which part of the plan needs to be conducted next according to the plan, and (c) inform the members of the team of that part.

The team can start the enactment of a process by activating it. The activation of a process requires the association of a process plan with a design project monitored and managed by the DPME (Figure 8). After the activation of a process, the DPME interprets the plan of the process and identifies the activity(s) following the start node. DPME monitors the enactment of the design process and analyzes how the team is following its plan. If there is any correlation between the process being enacted and the process plan; it reminds the team members of the tasks that they have planned to conduct, the resources that they

have planned to use and the standards with which they have planned to comply. The resource interpreter identifies the resources (time and human resource) allocated for the enactment of the first activity(s). It identifies the team members that were assigned to this activity (participants of the activity), updates the list of activities that were indexed for each team member and feed all the documents related to that activity to each participant's workspace (Figure 9).

3.3 Monitoring the Enactment of the Design Process

DPME enables the monitoring of the enactment of the design processes by allowing the observation of (a) the progress of a process (progress view), (b) the team's resource usage in completing a process or activity (resource usage view), and (c) the products (product view).

DPME constructs a progress view by determining which processes and activities are completed, suspended and not initiated at a certain time frame (Figure 10). Such a static view of the design project is constructed so that all members of the design team have a shared understanding of what tasks are completed and what tasks they need to complete next.

The DPME constructs a resource usage view by determining what resources have been used. The resource usage view describes the team's time and human resource usage by describing who has participated in which process and activity (who did what), how they have contributed to them (what products they produced), and how much time they have spent when contributing to those processes or activities (how long did it take). Furthermore, the DPME constructs and allows sharing of a product view. The product view lists and provides references to the products that have been developed as an input for or as an outcome of an activity or a process (Figure 4).

DPME supports the timely completion of the scheduled activities by monitoring the amount of time employed for conducting an activity and by comparing it against the amount of time allocated in the process plan. It informs the team members when they have over used their time resource.

3.4 Influencing the Enactment of a Process.

In the DPME, the members of the design team are given the authority and responsibility for influencing the enactment of a design process by (a) feeding additional information or knowledge and (b) providing negative or positive feedback (Figure 11).

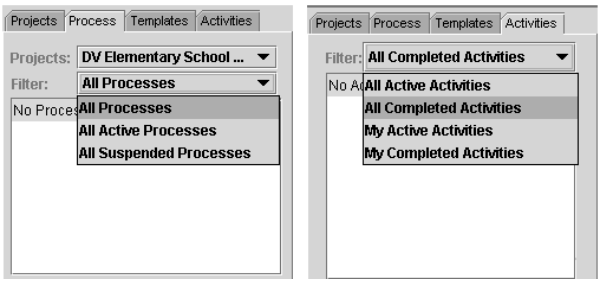

Figure 10. Listing the activities in a process and the processes in a design project.

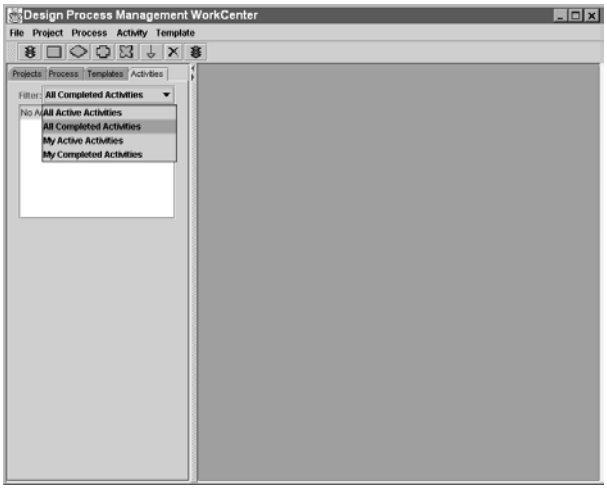

Figure 9. Listing the activities assigned to a team member.

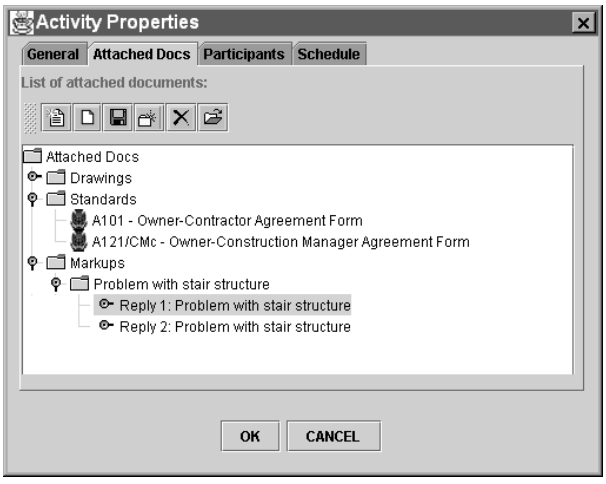

Figure 11. DPMS: Discussion of the design decisions.

Table 1. The phases of the DPME evaluation and the interview questions employed during each phase

Phases of the DPME Evaluation	Objectives	Corresponding Interview Questions
Inquiry of a participant's qualifications	Determine if a participant can be considered an expert of not	A Section – Question 1-7
Identification of the conditions required for collaborative building design	Allow the experts to identify the conditions they currently require and neeed from an effective collaborative building design environment	B Section – Questions 8-12
Demonstration of the DPMS and discussion of the effectiveness of the DPME	Allow the expert to understand the premises of the DPME	C Section
	Allow the experts to evaluate the effectiveness of the DPME in meeting the conditions required for collaborative building design	C Section – Questions 13-16

By providing additional information or knowledge, a member of the team affects the enactment of the design activity. For example, the decisions made or the information provided by the structural engineer influences the design of the floor plans if necessary. The design information and knowledge that each team member has access to are updated whenever there are any additions to the product model.

After monitoring the progress view, the resource usage view, and the product view of a project, any member of the team can give feedback and thus share his/her thoughts about how the team is performing. In DPME, the design team can give positive feedback for supporting the current trend; or give negative feedback to declare his/her discontent or to request a change in the trend. DPME allows free flow of feedback and sharing of feedback among all members of the team by constructing a shared discussion space, which acts as a repository for project feedback.

4 Effectiveness of a Distributed Process Management Environment

In this study, the researcher not only aimed to expand the theories of collaborative building design by developing and implementing a conceptual model of a collaborative building design environment, but also study the effectiveness of the DPME in meeting the conditions required for collaborative building design.

4.1 Methodology

An evaluation study was conducted for assessing the effectiveness of the DPME in meeting the conditions required for collaborative building design. In the DPME evaluation, a group of experts (N=13) were asked to discuss the current needs and expectations of the design teams from an effective collaborative design environment by identifying the capabilities and limitations of the currently employed collaboration methods and tools. For consistency, in each interview, the interview guide as shown in the Appendix was used. Table 1 provides a brief summary of the phases in the DPME evaluation, their objectives and the interview questions that were employed in each phase.

4.2 Findings and Discussion

The findings of the evaluation study illustrated that the design teams require to work in a collaborative design environment which not only allows the exchange of information about the artifacts being designed, but also the communication of interrelated team members, the creation of a shared understanding of the team's vision and progress, the shared creation and discovery of artifacts and vision, and the self-sustainability of the effective team performance.

Table 2 shows the conditions that the experts were expecting from an effective collaborative design environment. The experts stated that such an en-

Table 2. The mean and the standard deviation of the effectiveness of the DPME in meeting the conditions required for collaborative design.

Nature of the Condition	Condition	Mean (M)	Standard Deviation (SD)
Team Communication	Communication of the project information	4.00	.58
	Communication of the information of the designed products	4.62	.48
Shared Understanding and Vision	Shared understanding of the team's vision	4.00	.41
Shared Creation and Discovery	Planning of the activities in a design process	4.62	.51
	Scheduling of the activities in a design process	4.38	.51
	Planning of the resources for the enactment of design activities	4.38	.51
	Description of the standards for regulating the enactment of design activities	4.77	.44
	Collaborative decision making	4.69	.48
Self Sustainability	Assessment of the progress of a design project	4.38	.51
	Determination of the effectiveness of the team in resource allocation	3.77	.60
	Shared authority and responsibility for sustaining effective team performance	4.77	.44

vironment should allow all the team members to make decisions in their isolated workspaces and coordinate those decisions with others being made. The experts had conflicting ideas about who should have the authority and responsibility for managing and sustaining the enactment of design projects. Some argued that all the team members should be able to introduce solutions to conflicting situations without the approval of a higher authority. Others argued that the authority should be given only to a selected management team. However, all agreed that an effective collaborative design environment should allow all the members to act according to the team's game plan. All the team members should have an understanding of the progress and consequences of their work. They should influence the enactment of processes by providing continuous feedback.

The findings of the DPME evaluation showed that the DPME effectively supports (a) the team communication, (b) the creation of a shared understanding of insights and vision, (c) the shared creation of design solutions and discovery the team's visions, and (d) the sustainability of effective team performance. The effectiveness of the DPME was rated positively (Mean above 3.77 and standard deviations less than .63) (see Table 2). The experts also recommended several enhancements to the DPME. They suggested that the DPME allows the management of changes in design decisions by enabling them to monitor and control of such changes. It also allows the easy search for and retrieval of different versions of design documents according to content and context.

Conclusion

This study explored the effectiveness of the distributed process management environment (DPME) in meeting the conditions required for collaborative building design. The findings of the DPME evaluation showed that the DPME is effective in supporting design teams in four major areas. It effectively supports (a) the team communication, (b) the creation of a shared understanding of insights and vision, (c) the shared creation of design solutions and the discovery the team's visions, and (d) the sustainability of effective team performance. However, the discussions made by the participants and the data collected during the DPME evaluation (i.e., the exhibits provided by the participants to further support their discussions) showed that the DPME can be further en-

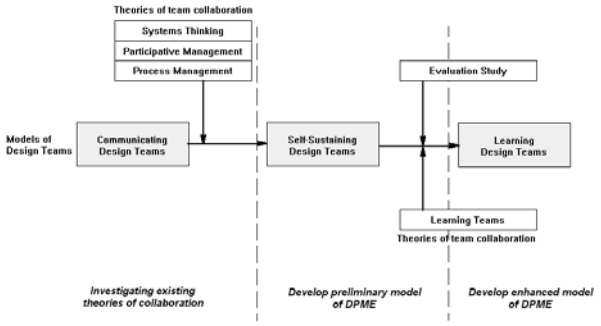

Figure 12. The evolution of the theory of collaborative building design

hanced by improvements in (a) the shared space model, (b) the feedback and process communication and representation methods, (c) the control of design and process decision making, (d) the standardization of design communication and representation methods, and (e) the collective learning procedures of design teams.

A post facto of such a demand, the researcher proposes to enhance DPME by introducing the learning teams concept (Figure 12). An enhanced model of DPME is expected to support the incorporation of the lessons the team members learn about effective communication and the standards they develop for this purpose. It allows incorporation of the best-practice standards, methods, or tools. It not only facilitates the communication of process plans by the method employed in the DPME (i.e., activity-flow diagram) but it also enables the structuring and viewing of the design processes in standards ways. This requires a flexible collaboration environment, which allows extension or limitation of its capabilities in regard to the lessons learned during various design projects. Such an environment is expected to be scalable to varying needs of collaborating design teams and extendible to accommodate standards that suggest effective ways of achieving collaborative building design.

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