Computer-Supported Virtual Collaborative Learning and Assessment Framework for Distributed Learning Environment

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Submitted to the Department of Civil and Environmental Engineering in partial fulfillment of the requirements for the degree of

Master of Science

at the

Massachusetts Institute of Technology

June 2002

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ABSTRACT

Project-based distributed collaborative learning in curricular teaching and organizational training environment, as preparation for education, engineering and research, are being revolutionized by rapid advances in information and communication technologies. Distributed data, application, students and instructors have to be brought together into an electronic virtual collaborative learning environment, which bridge the geographical and temporal barriers of the distributed learning team members for the same learning objectives. However, few instruments are available to measure learning and interaction effectiveness and help to adjust dimensions relevant to collaborative learning such as teaching practices, student attitudes and behavior, or peer support. Through this research a Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) has been built up and highlighted in this thesis with Distributed Team Interaction (DTI) Space, Virtual Team Collaboration (VTC) Space, and Collaborative Learning Assessment (CLA) Space, which is based on pedagogical frameworks and educational theories that support collaborative, distributed (distance), and project-based learning. This framework captures the key dynamic dimensions and the iterative nature of collaborative learning process: from carrying out learning interactions and collaborations in the distributed team interaction space and team virtual collaboration space; to observing the barriers to effective learning and interaction by evaluating the effectiveness variables in the collaborative learning environment; to mapping individual and team performance to Collaborative Learning Team Effectiveness Continuum and comparing them with the desired state; to identifying areas of improvement and making adjustments to remove these barriers in order to increase the learning effectiveness and maintain the team health. This thesis also emphasizes the design of Multi-Dimensional Collaborative Leaning Assessment Model with Learning Assessment Space and Assessment Matrix from various perspectives, which are effective abstraction and realization for collaborative learning assessment. Based on this framework, a working prototype of Collaborative Learning Assessment Support System (CLASS) has been designed and implemented as a useful instrument by using advanced web solutions and software technology to improve the overall collaborative learning effectiveness and team health.

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ACKNOWLEDGMENT

May 10, 2002

I would like to thank my advisor Prof. Feniosky Peña-Mora, for the unstinted guidance for my research and support in the completion of my thesis in MIT. I would also like to express my immense gratitude for Joan McCusker for her constant help throughout the two years of my stay here for learning and working. Her help in everyday life and office routines is invaluable.

Special thanks to all the past and present members of IESL and my dear officemates who I have worked closely in the past two years: Sudarshan Ragunathan, Chang Kuang, Victor Viteri, Sugata Sen and Sanjeev Vadhavkar, for sharing knowledge, giving advices and helping with great patience, especially for Sudarshan Ragunathan who I spent most of my nights in the office with and share encouragement with to overcome the frustration. The days and nights all we spent together make a mixed experience but an altogether enjoyable one in my memory.

I have to mention my dear friends in MIT for great acknowledgement: my roommate Jian Li who has shared a lot of thinking with me and handled the everyday life troubles together, Xi Zhang, Haibo Chen, Rong Wang and all my friends around, as we share feelings and they help me to have a most enjoyable time outside school.

Thanks MIT for giving me the chance and tough time to study in the most prestigious and challenging environment in the world to absorb knowledge and discover the most valuable thing in the life: how to conquer myself. Also thanks MIT I-Campus research group and Microsoft who provided the financial support and initiative for the research.

Finally, I would like to express greatest gratitude for my family from whom I have always received a whole lot of love, support and encouragement whenever and whatever I am pursuing, and the new born niece who has brought a lot of fun for the whole family.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Chapter 1 Introduction

1.1 Research Motivation

1.1.1 Learning Transition

Teaching and education as preparation for engineering and research are being revolutionized by the progress in information and communication technology, not only in the curriculum learning but also in the organizational training environment. Globalization of processes, products and markets has also fuelled a transition to new organizational forms. The virtual team, consisting of individuals probably learning and working from locally or globally dispersed locations united by a common goal, relying on obtaining member participation and coordinating individual effort in collaborative learning and productive work is such a transition of educational and organizational form. Distributed, collaborative learning and working for projects have become the norm in industry, thus the students and engineers in educational or industrial environment are required to prepare for the realities of working in the era of globalization.

The new internet-based information and communication technologies have not only brought tremendous changes about learning, but also enabled more effective and economical team efforts among locally or geographically distributed team participants in the project-based, collaborative and distance learning environment. Distributed data, distributed application, distributed participants and distributed management have to be brought together into an electronic virtual learning and interaction space shared by everybody with possibly different nationality, cultural background and expertise, enabling participants for same goal to work in any virtual teams at any place, any time. Learning is not only an individual behavior any more, but also a combination of interaction, communication, collaboration, collocation and coordination within the social environment.

1.1.2 Project-Based Learning

Project-based learning (PBL) is an instructional strategy designed to induce conceptual change through cognitive conflict produced during a learner's active (re) construction of knowledge (Gijselaers, 1995). The cognitive conflict or puzzlement that arises when one's conceptual view is challenged by new information is the stimulus for learning, and determines the organization and nature of what is learned. The "problematic," according to Dewey, is what leads to and is the organizer for learning (Dewey, 1938; Rochelle, 1992). Along these lines, Gibbs (1992) asserts that motivational context, learner activity, interaction with others, and a well-structured knowledge basis result from posed problems. The challenge of solving problems in a learning environment should also be motivating and authentic to the instructor as well as to the students. Motivation for learning, a common result of PBL comes from choosing topics, tasks, and goals that everyone truly cares about and by providing students with an opportunity to create and have ownership of their creation.

In PBL scenarios, problems and projects must also be designed to simulate "real world" contexts or actually involve students in "real world" situations and conversations, as well as the unpredictability of real situations. Such a context helps students develop the skills required for working in a rapidly changing global economy and helps improve both the retention and functional use of knowledge, which in turn induces a deeper understanding of what is to be learned.

There are two other essential features of PBL that seem to impact students' learning significantly: the role of the tutor and the format of the problems. The tutor must focus on helping students acquire self-directed learning skills, while finding a balance between allowing students to discuss and explore issues, and intervening to enforce critical learning issues. The instructors need to get involved with the planning and process of the group collaborations and will be often helping students articulate the alternatives they had before them individually as well as collectively. The instructor(s) would often look for opportunities to demonstrate how in industry, collaboration rather than individual problem solving is a better way to solve more complex problems. Students come to see this as they would get feedback on how well their ideas compared to their classmates and then have the opportunity to brainstorm solutions to problems they might find difficult to solve on their own.

1.1.3 Distributed (Distance) Learning

When instructors and students are physically separated from each other, yet the learning experience for students still continues to be planned, this is called distance education or distance learning. More specifically, distance education is "formal, institutionally-based educational activities where the learner and teacher are separated from one another, and where two-way interactive telecommunication systems are used to synchronously and asynchronously connect them for the sharing of video, voice, and data-based instruction" (Simonson, 1995). According to the Equivalency Theory (Simonson, 1997), a new theory crafted to guide the implementation of distance education, "those developing distance education systems should strive for equivalency in the learning experiences of all students, regardless of how they are linked to the resources or the instruction they require" (Simonson, 1997). Crafting a distance learning course that honors equivalency requires tremendous planning before the course begins as equal access to all the course materials needs to be assured for all class participants. Educators in distance learning environments must subsequently utilize the features of virtual environments (i.e., discussion and information repository spaces), and allow for the technological and cultural challenges of connecting distributed participants. Further, the work should proceed in a fairly predictable manner. This "predictability" is critical for students to know where to find resources (people as well as readings or multimedia files) and schedules so they can do their work as it is assigned.

1.1.4 Collaborative Learning

Unlike solitary learning, collaborative learning can heighten student motivation as well as catalyze social interaction and integration. Specific academic skills such as high-level reasoning, cognitive thinking, and an increased willingness to take intellectual risks also evolve from collaborative learning because collaborating students "share the process of constructing their ideas, instead of simply laboring individually. The advantages of this collective effort are that students are able to reflect on and elaborate not just their own ideas, but those of their peers as well. Students come to view their peers not as competitors but as resources. Mutual tutoring, a sense of shared progress and shared goals, and a feeling of teamwork are the natural outcomes of cooperative problem-solving, and these processes have been shown to produce substantial advances in learning" (Strommen, 1991).

One example of how working collaboratively is better than working alone when solving conceptual and complex tasks comes from a study by Gauvian (1994). In this study, "pairs generated more attempts to solve the problem (an unsolvable spatial logic problem), less often erroneously believed that they had solved it, and more frequently attributed their lack of success to the "unsolvability" of the problem than to the problem being too hard for them. The pairs that collaborated (rather than taking turns) made suggestions regarding each others' ideas and remembered and kept track of prior moves and attempts to a greater extent, monitoring and editing plans together, thereby supporting each other in developing novel solutions" (Rogoff, 1998).

The approach of collaborative learning differs from traditional perspectives on leaning that focus on acquisition of knowledge by isolated individuals and on the efficiency, technologies, and techniques of learning that stem from school practices. Collaborative learning requires interaction and exchange among learners as they share experiences and solve problems cooperatively while fully engaging themselves with each other's ideas and opinions, which can foster progress within a collaborative learning environment.

1.1.5 Distributed Virtual Team and Distributed Collaborative Learning

(Katzenbach & Smith, 1993)'s definition among the many definitions of 'team' is: "... a team is a small number of people with complementary skills who are committed to common purpose, performance goals, and approach for which they hold themselves mutually accountable..." Distributed Virtual teams are cross-functional teams that operate across space, time, and organizational boundaries with members who communicate mainly through electronic technologies. There are several types of virtual teams, depending upon task, membership, and role. Distributed Virtual teams are more complex than regular teams because they cross boundaries of time and distance and because communication relies entirely on technology. Virtual teams must over communicate; team leaders must be much more deliberate and structured in their communication and coordination efforts.

This is the age of the networked and global organization. The industrial world is shifting to a stage where millions of team leaders and members may belong to geographically dispersed or virtual teams and distributed, collaborative projects are becoming the norm in industry. Not only in organizational environment, distributed team members need to share knowledge and experiences, and accomplish continuous learning for specific tasks, but also in educational curriculum environment remotely located schools may carry out cooperative teaching for distributed students or use projected-based collaborative learning for geographically or virtually dispersed students to prepare their students for the realities of future distributed work environment. Thus, the distributed virtual team becomes the centric unit of the collaboration.

In this dissertation, we generalize the concept of collaborative learning as an educational or learning methodology integrating the project-based learning, distance learning, and traditional collaborative learning for the distributed virtual team. In the distributed collaborative learning environment, grouping and pairing of students for the purpose of achieving a common academic goal, accomplish complicated project work and fulfill the same target. The students are responsible for one another's learning as well as their own to increase the overall effectiveness of the learning. Members may have diversity in skills, performance level, background, culture, across physical locations, time zones and even organizations. Members with diverse expertise need to share information, ideas, knowledge and skills, thus most learning processes include communication, knowledge exchange and teamwork for project

1.1.6 Virtual Collaborative Learning Environment Framework Motivation

This period of radical organizational change has also been accompanied by an equally radical change in communication technologies, allowing teams to collaborate both in synchronous and asynchronous way to be effectively reconstituted from formerly dispersed members across the globe, thus realizing the competitive synergy of teamwork and exploiting the burgeoning revolution in telecommunications and information technology. Technology driven collaboration systems could enable distributed teams to be more effective by increasing the quality and quantity of the collaboration. The Internet has given virtual teams a global network for communication and allows applications to access data from anywhere in the world.

To support successful collaborative learning for distributed team, an effective Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) has been well structured in this research to accomplish the whole collaborative learning process while maintaining the learning and interaction effectiveness and team development health. This framework consists of three main spaces (models): Distributed Team Interaction (DTI) Model, Team Virtual Collaboration (TVC) Model and Collaborative Learning Assessment (CLA) Model. Among these models, this thesis will focus on the Distributed Team Collaborative Learning Assessment model, which is the guardian for an effective and healthy collaborative learning.

Distributed Team Interaction (DTI) Space Motivation

There are more complicated constrains for a distributed team than the traditional teamwork:

- Distributed teams/classes cross boundaries related to time, distance (geography), and organization. It's difficult especially when organizational processes are tied to a local perspective with different time zones.
- Distributed teams/classes are composed of people from different cultures. The presence of these people from different cultures introduces cultural barriers that increase the complexity of the collaborative effort as the ways people do work vary greatly and it is often difficult to understand and acknowledge the different ways in which people approach their work.
- Distributed team members' communication, information sharing technical competence may vary from site to site among the workforce, technical resources and their comparative ease of use, their reliability, response time (speed transmission), capability, simplicity, accessibility, related training and support resources. This may result in dissatisfaction and inefficiency in sharing information and working together.
- It's hard to lead a distributed team effectively and insure the team's development in a healthy way, due to their different background, knowledge, understanding and roles in the teams/classes.
- The diverse issues mentioned related to bridging temporal, cultural, organizational barriers make the interaction process more complicated and tougher to define and maintain a common goal definition of the distributed team/class and to lead the team to achieve common goals and reach final decisions.

By enabling team interactions via non-traditional media, unrestrained by geographical and temporal constraints to overcome the existing barriers, communication technologies have actually expanded and transformed the conventional team interaction space. This merger of physical space with digital has created a new era of team interaction spaces, one where organizational, technological and spatial dimensions play a significant role. Taken together, organizational, technological and spatial dimensions constitute a dynamic team interaction system: a change in any one of the dimensions requiring a reinforcing change in the others (Sen, 2001). In creating and managing such teams, it is more important for Distributed Team Interaction (DTI) Model to understand the special dynamics of virtual groups, to design the infrastructure, to build up the interaction protocols, and to clarify the roles and responsibilities of team participants and the team as a whole, orient the members than the pure interaction techniques.

Team Virtual Collaboration (TVC) Space Motivation

Early generation solutions for coordinating the work of distributed teams have proven inadequate to the task. These include email, conference calls, threaded discussion software, "e-rooms," rich media presentation technologies, and real-time online meeting applications. These technologies are valuable, but they focus on providing people with a shared view of common data and in themselves cannot provide an adequate infrastructure for teams that deal with multiple projects in multiple sub-teams, comprised of individuals who have different roles and responsibilities and have underlying dynamics that impact their process. They are not optimized for helping people need to take the next step - to talk together, to interact with shared applications in distributed computing environment, to analyze data, to share knowledge, or make decisions in real-time environment.

The Virtual Collaborative Learning Environment must map the four-phase process of collaboration into the virtual environment. It should allow for the customized **design** of the collaboration; facilitate sharing **content** about which the collaboration occurs; enable people to **process** that content and make decisions; and structure the resulting **actions** to be taken. The required communications processes for online collaboration are complex. They often extend into many interactions over a period of time, between people who have different roles and responsibilities – just as they do in face-to-face environments for collaborative learning. Thus, Team Virtual Collaboration (TVC) model must support complex, distributed data and application intensive sharing and collaboration with synchronous and asynchronous communication capability over networks for human interactions.

1.1.7 Distributed Team Collaborative Learning Assessment Space Motivation

Cognitive Learning (Metacognition), or thinking about one's own thought-processes, requires higher-order knowledge, "knowledge about how to get knowledge and understanding" (Perkins, 1995). Mental Management, another term for metacognition, is defined by Jay et al. (1995) as "the art of reflecting on and guiding one's own thinking processes." It is generally assumed that metacognition affects the use of knowledge (Glaser, 1991) as it requires learners to be aware of how information is relevant and useful to them and their experience — necessary skills for both the academic and professional worlds.

To have more effective and successful learning and teaching results, besides the Project-Based Learning, Collaborative Learning, and Distributed (Distance) Learning constitution of distributed team collaborative learning, the learning practice need to move to the higher educational level, Cognitive Learning (See Chapter 2), as it will

- Help student move from doing to reflecting
- Encourage student to focus on deep thinking rather than surface memory
- Reflect on and guide one's work to better understand the knowledge
- Higher-order knowledge about how to get knowledge and understanding
- Record one's own thinking and working processes - Collective Memory
- Avoid repeating mistakes
- Promote elaboration of new ideas
- Build up intellectually self-watchful, self-guiding and self-assessing skills
- Get better sense of each other's strengths and weaknesses

Therefore, in the distributed team collaborative learning process, one of the important activities includes assessment of collaborative learning and team interaction effectiveness, and evaluation of individual or team development health during the whole learning and working process. This evaluation provides solutions to the collaborative learning team regarding what it should be doing to conduct student Cognitive Learning practices, to guide the individual's learning process and self-development, and to improve the team interaction effectiveness and healthy cooperation.

For Individual participant in the collaborative learning process, learning assessment will

- Help individual conduct Self-Cognitive Practices
- Guide individual learning (at a level-appropriate pace in different phases)
- Evaluating individual understanding of knowledge
- Improve effectiveness of learning
- Assess individual performance and contribution to teamwork
- Encourage participation in project-based teamwork
- Stimulate healthy cooperation between participants
- Track student's responses and interaction
- Monitor individual learning process and progress

- Analyze individual learning behavior
- Collect feedback and suggestion about learning environment (Learning Process, Instructor's Teaching, TA Capability, Course Settings, Infrastructure and Collaboration Technologies)

For the team of collaborative learning, it will

- Lead team/class development in a healthy and effective way
- Control team learning objectives and maintain team focus
- Provide team assessment metric and guidelines
- Monitor team collaborative learning behavior and progress
- Guide team cognitive learning practices
- Analyze team collaborative learning characteristics
- Adjust current team dynamics between team various participants
- Inform team/class of observation about collaborative learning
- Feedback learning results and performance to students
- Identify and stress barriers of learning effectiveness and team health
- Form sense of each individual's strengths and weaknesses
- Analyze efficiency of assisted communication technologies and infrastructures
- Adjust four dynamic dimensions of collaborative learning environment
- Shape solution to improve course arrangement, teaching process and use of information technologies

Over the past decade, state and national policy makers have promoted systemic reform as a way to achieve high-quality science education for all students and many electric virtual learning instruments and systems have been developed to conduct more effective and convenient educational with the development with rapid development of communication and information technology. However, most of the traditional virtual collaborative learning environments only focus on synchronous or asynchronous communication technology, team collaboration, information sharing and data repository, few instruments are available to measure changes in key dimensions relevant to systemic reform such as teaching practices, student learning process and attitudes, and peer support for collaboration. They are lack of

- Collaborative learning and teamwork guidance
- Reflection and feedback system
- Progress assessment and performance evaluation
- Learning behavior monitoring and analyzing
- Collaborative learning and collaboration effectiveness control
- Team cooperation and development assistant

Therefore, in the new generation Virtual Collaborative Learning Environment Framework, another key component, Collaborative Learning Assessment (CLA) Model, has to be built up, to fulfill the tasks of collaborative learning assessment, to evaluate student progress, interactions, motivations and individual effort in teamwork, to improve the teaching and individual or team effectiveness of collaborative learning, and to help team develop in a healthy way. Based on this framework, the research focuses on providing Learning Effectiveness and Team Health Model and Multi-Dimensional Collaborative Learning Assessment Model, as well as a system design and working prototype for the collaborative learning assessment space by using advanced web and communication technology. This prototyping system, called CLASS (Collaborative Learning Assessment Support System), has been implemented and tested in teaching and learning practices of MIT Distributed Systems Engineering Lab (DiSEL) course 1.118 - Distributed Development of Engineering Information Systems and MIT course 1.040/1.401 – Project Management, led by the Intelligent Engineering Systems Laboratory (IESL) at MIT.

1.2 Research Background

1.2.1 MIT I-campus Project

This research project is part of MIT iCampus project, "Collaborative Active Learning Tools to Enrich Engineering Education".

MIT iCampus was initiated in October 1999 as a five-year research alliance between MIT and Microsoft Research to enhance university education through information technology. The goal is to demonstrate leadership in higher education by sponsoring innovative projects with significant, sustainable impact at MIT and elsewhere.

Dubbed "I-Campus," the alliance involves cooperative projects among students, faculty and researchers at MIT and members of Microsoft Research. In addition to assigning several staff members to I-Campus, Microsoft will allocate an estimated $25 million over the course of the five-year effort.

Based on a shared commitment to excellence in technology-enhanced education, Microsoft and MIT focus on methods and technologies that could set the pace for university education in the next five to 10 years. In an effort to achieve broad impact, both MIT and Microsoft are committed to engaging additional academic and industry partners and to producing materials that adhere to open standards, with results and source code that can be widely published and disseminated.

I-Campus will involve research and development in three broad areas in which information technology has a major impact on university education:

- New pedagogical approaches and structures. Possibilities include remote access to laboratory instruments, new software tools for delivering education content, new tools to aid student learning such as tutoring and mentoring at a distance, and Web-based virtual museums.
- Integrating information technology concepts and methods throughout university education. Examples include large-scale collaborative engineering design, the study of complex systems, and the creation of information-based curricula across traditional disciplinary boundaries.
- Addressing the changing environment of university education. Options include providing education at a distance and lifelong learning to a larger community, and the impact of digital information technologies on academic publishing.

I-Campus will address education from the perspective of learners (students, alumni), educators (teachers, mentors) and administrators (managers). The alliance aims to create better learning environments for students, better teaching and curriculum development environments for faculty, and better infrastructure for university administrators to effectively manage and provide information services.

1.2.2 Collaborative Active Learning Environment Initiative

The "Collaborative Active Learning Environment" project is aimed at improving learning in engineering education through a combination of computer based simulation, creation of collaborative environment using IT and integrating assessment at a variety of levels.

Simulation is used to allow students to observe the performance of natural and artificial structures and systems. Students learn by observing the performance as they change characteristics of systems and structures and of boundary conditions. They learn actively by being required to make predictions and then being able to compare them to the behavior. Most important for the engineering context is the fact that required performance needs to be defined by the student and can be satisfied in different ways, in other words, the problems are open ended.

Modern engineering is based on teamwork. IT can greatly facilitate collaboration by having team members continuously interact while designing and analyzing structures and systems. This can be done independently of the physical location of the team members. The IT based environment not only allows students to jointly design but also allows one to assess the effectiveness of collaboration and suggest improvements.

Learning assessment is fully integrated in the simulation and collaborative environment. It occurs at a variety of levels starting from assessing the effectiveness of the IT based learning tools to assessing what students learn, don't learn and why, and to providing feedback on the effectiveness of classroom teaching.

1.2.3 Collaboration Research at MIT

Intelligent Engineering Systems Laboratory (IESL) at MIT has three main objectives:

(1) Study major challenges in the civil engineering industry;

(2) Conceptualize solutions to those challenges;

(3) Use information technology to implement those solutions with the support of organizational change and process redefinition.

One of the current flagship projects of the laboratory, the Da Vinci Initiative (Peña-Mora, 1995), is the application of computer and communication technologies in support of distributed collaboration in engineering projects.

The DaVinci Initiative investigates the use of information technologies to improve online collaborations. The focus of the research at MIT has been in the area of meetings, both online and physical, and how the participants interact, leading to some general observations of collaborations and their participants. Of these observations, some general observations of collaborations pattern, protocols and rules used during a meeting have been the primary focus of research at MIT. Meeting protocols establish how information is shared within the collaboration and how control of the meeting is established. CAIRO (**C**ollaborative **A**gent **I**nteraction and Synch**RO**nization) was developed as a realization of the collaboration research at MIT, which is a meeting environment that encompasses many of the research results such as membership and meeting protocol enforcement. Adapting a strong implementation of meeting protocols, CAIRO uses the Internet to communicate in a highly structured environment that includes protocol-enforcing agents to simulate a physical meeting with a facilitator. This on-line meeting environment forms the basic component of the Team Virtual Collaboration (TVC) Module. To test some of the hypotheses developed in the Da Vinci Initiative, the Distributed Systems Engineering Lab (DiSEL) was established and several collaborative learning courses has been implemented under pedagogical methodologies and collaborative learning framework. The Distributed System Engineering Lab (DiSEL) course is an experimental practicum designed to prepare graduate engineering students for the realities of working in the era of globalization. DiSEL was created to help students learn about the development life cycle of systems while designing and developing a marketable, innovative, and reliable product in a distributed collaborative environment.

1.3 Thesis Roadmap

Chapter 1 gives the introduction to the research background and motivation for virtual distributed collaborative learning environment and collaborative learning assessment.

In Chapter 2, educational theories and methodologies have been researched and a pedagogical framework for virtual distributed collaborative learning and assessment are created, based on Teaching For Understanding (TFU) and Theory One (TO) educational methodologies as well as Project-Based Learning, Collaborative Learning, Distributed Learning and Cognitive (Metacognition) Learning theories. Moreover, barriers to the distributed collaborative learning effectiveness and team health have been discovered and categorized that guide later design of the Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) and need to be overcome by the system implementation.

Chapter 3 highlights the Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) built up through the research, which is based on the developed pedagogical framework, and analyzes the dynamic dimensions of the framework. This chapter also elaborates Distributed Team Interaction (DTI) Model and Virtual Team Collaboration (VTC) Model that are two main components of this framework.

Chapter 4 is the focus of the thesis that presents the new concepts of the more flexible Multi-Dimensional Collaborative Learning Assessment Model and effective assessment processes. This model captures the Collaborative Learning and Assessment Iterative Cycle and creates Collaborative Learning Team Interaction Effectiveness Continuum used for the collaborative learning process. The learning effectiveness and team health assessment model elements and variables have been identified and summarized before introducing the model. This chapter emphasizes on defining and analyzing the Multi-Dimensional Collaborative Learning Assessment Model with enhanced Collaborative Learning Assessment Space and Collaborative Learning Assessment Matrix. More illustrations are carried out for the Collaborative Learning Assessment Space and Collaborative Learning Assessment Matrix through the implementation in CLASS system.

Chapter 5 focuses on the system design for an easy-used web-based Collaborative Learning Assessment Support System (CLASS) based on Multi-Dimensional Collaborative Learning Assessment Model. It includes the system general architecture, system components, functional model, system assessment contexts and system processes for effective collaborative learning assessment.

Chapter 6 describes the CLASS system implementation with system data modeling, system functional modeling and features illustrated by screen dumps from both organizer and participant perspectives. System implementation requirements are analyzed and corresponding technologies are selected with consideration of high flexibility, scalability, reliability and performance. After finishing the system, a critical evaluation of the CLASS system are conducted by comparison with some major assessment and survey systems in the market, and the advantages of the system are highlighted.

In Chapter 7, the CLASS system and Multi-Dimensional Collaborative Learning Assessment Model have been tested through a "real world" case of MIT course 1.118. The collaborative learning practices, learning assessment contexts and assessment process of the course are described with abundant assessment results analysis generated by CLASS system.

Chapter 8 draws conclusion on current research and summarizes the accomplishment have been achieved. Last but not least, the potential research areas about model improvement have been identified and revealed for future work, such as more flexible assessment model, more interactive assessment model and more intelligent assessment model.

Chapter 2 Collaborative Learning and Assessment Pedagogical Framework and Literature Research

2.1 Pedagogical Framework

To assure that laboratory setting and collaborative learning process do in fact help students gain real world experience, and support them throughout the learning process, the Virtual Collaborative Learning and Assessment Framework should integrate pedagogical (educational) frameworks and theories that support collaborative, distributed (distant), and project-based learning.

Distributed, collaborative projects are becoming the norm in industry. The instructors of the collaborative learning course therefore need to well prepare their students for the realities of this work environment and they need to create a comparable educational setting. However, there is a critical difference between an educational and industrial environment: in classrooms special considerations need to be made for guiding students through their work at a level-appropriate pace, assessing student performances based on their level of understanding, and supporting student reflection. This shaping of students' experience therefore requires more of a planned and controlled setting than a real world, unpredictable development situation allows. To compensate for this discrepancy, the instructors need to develop a flexible course schedule and allow for variable grade requirements. With the aid of the pedagogical frameworks Teaching For Understanding (Wiske, 1998) and Theory One (Perkins, 1995), the instructors are able to articulate and prioritize their teaching goals, as well as students' expected performances, so the curriculum is cohesive and focused even though the project is ill defined.

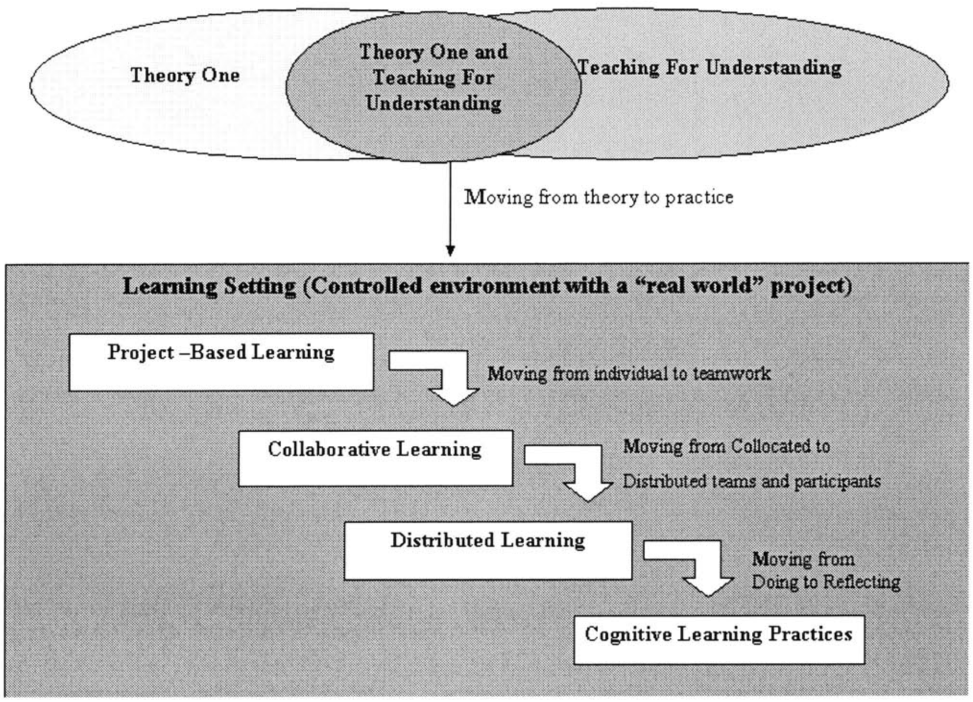


Figure 2-1: Pedagogical Framework for Collaborative Leaning and Assessment

To support the "Real World" technology-supported, project-based, distributed (distance), collaborative learning environment, the Teaching For Understanding (TFU) (Wiske, 1998) and Theory One (TO) (Perkins, 1995) frameworks are integrated to form the foundation of the pedagogical model, and Project-Based Learning (De Grave et al., 1996), Collaborative Learning (Slavin, et al., 1985), and Distributed (Distance) Learning (Simonson, 1999) theories, as well as the theory of Metacognition (Jay, et al, 1995), are utilized to plan specific course activities. These theories are chosen because they support the distributed collaborative learning environment the course instructors created. In addition, they require learning by doing and this adheres to the constructivist school of thought that believes students construct new ideas by "assimilating new information to pre-existing notions" (Strommen, 1991). In the process of integrating new information, learners "modify their understanding ... and their ideas gain in complexity and power" (Strommen, 1991). Constructivism therefore encourages educators to design courses that challenge students' experiences, instincts, and understandings so they can develop their ideas in depth and detail.

Project-Based Learning, Collaborative Learning, and Distributed (Distance) Learning theories, and the theory of Cognitive Learning, have been selected for the virtual collaborative learning for distributed team and they complement each other in practice. Project-Based Learning stresses helping students work at their own pace on a problem of great relevance to the real world, and Collaborative Learning encourages teamwork over individual or isolated attempts to solve very complex problems. Given the distributed element of the learning, Distributed (Distance) Learning theories help explain and support the collocated team dynamics of distance education. To keep the educational aspect of the course and learning at the fore of the work, cognitive learning practices were used to help students reflect on their learning and work experience and evolve the learning practice into a higher educational level. Based on the framework, given the exploratory nature of the class, all work take place in a laboratory setting in which students are encouraged to experiment with their ideas, the educators organize their courses around what it is they most want students to understand and the system development process specifically.

2.2 Pedagogical Foundation and Methodology

2.2.1 Teaching For Understanding and Theory One

Teaching for Understanding (Wiske, 1998) and Theory One (Perkins, 1995) together form the basic foundation of the DiSEL pedagogical model. These frameworks help educators organize their courses around what it is they most want students to understand. By asking instructors to consider their educational goals and subject matter in terms of the understanding they want students to gain, TFU and TO help them convey information to students in relevant and, ideally, interesting ways. The five organizing elements of the TFU framework are 1) Overarching Understanding Goals, 2) Throughlines, 3) Generative Topics, 4) Performances of Understanding, and 5) Ongoing Assessment. A worksheet for instructors using TFU has been developed by TFU researchers to help guide them through these five planning elements (See Table 1). The worksheet highlights specific statements related to each of the elements of TFU. For example, to develop their Overarching Understanding Goals, instructors are to finish statements such as "The thing I most want my students to understand after this course..." or "Students will understand...." By answering these statements, instructors can identify exactly what they want students to be learning from them and accordingly, they can organize their curriculum and assess student work based on their Understanding Goals.

Table 2-1: The Teaching for Understanding Framework (adapted from Wiske, 1998)

<table>
<tr><td colspan="2">Overarching Understanding Goals and Throughlines
To develop these Overarching Goals,
Instructor(s) complete the following statements:
The thing I most want my students to understand after this course are ...
Students will understand...

To develop Throughlines, the Instructor(s) should ask the following questions:
What type of experience do I want my students to have?
What do I want students to be thinking about throughout their work?</td></tr>
<tr><td>Generative Topics
To develop these topics, the Instructor(s) respond to the following questions:

"What topics strike you as being the most interdisciplinary?"
and
"Which topics do your students find most interesting?"
and
"Which topics do you find most interesting?"</td><td>Unit-Long Understanding Goals
To develop these goals, the Instructor(s) complete the following statements:

"Students will understand...
and
"The questions I'd like my students to be able to answer are ... "</td></tr>
<tr><td>Performances of Understanding
To develop these performances, the Instructor(s) complete the following statement:

"Students will build toward achieving the understanding goals by ... "</td><td>Ongoing Assessment
To develop the assessment for students' work, the Instructor(s) complete the following statements or question:

"Students will get feedback on their performances by... "
or
"How will students know how well they are doing?"
and
The criteria for each performance will be... "</td></tr>
</table>

Throughlines are questions that, when answered, should demonstrate an understanding of the Overarching Understanding Goals. Some educators have students write their own Throughlines to assure student interest and commitment to the work, but regardless of who writes the Throughlines, they should be interesting enough for both instructors and students to answer throughout an entire course or unit. Throughlines can therefore keep class participants motivated, as well as help keep classes relevant, as any lesson or activity should in some way help students answer the Throughlines. Questions to consider when developing Throughlines include: "What type of experience do I want my students to have?" and "What do I want students to be thinking about throughout their work?" Good Throughlines should help bring to light the Understanding Goals as well as the central, or generative, topics an instructor will focus on during a course.

Generative Topics are "central to a domain or discipline, accessible and interesting to students, interesting to the instructor, and are connectable to students' previous experience (both in and out of the classroom), and to important ideas within and across disciplines. They often have a bottomless quality, in that inquiry into the topic leads to deeper questions" (Wiske, 1998). Generative Topics in the DiSEL course include "the roles involved in the system development process" and "the life cycle of system development." These Generative Topics were easily identified in the curriculum and emerged by answering questions such as: "What topics strike you as being the most interdisciplinary?" "Which topics do your students find most interesting?" and "Which topics do you find most interesting?" Often the topic to be taught is the only information an instructor has to begin preparing for a course, so the Generative Topics may be determined before any planning can occur.

The DiSEL Lab course is continuously changing and its Throughlines are slowly evolving based on the five Generative Topics of the class: The System Development Life Cycle, Collaboration, Collective Memory, Technology, and Entrepreneurship (see Chapter 7).

These Throughlines help guide the inquiry and work of the students throughout the distributed team collaborative learning course so that the knowledge gained in the class connects to a bigger picture that provides an integrated view of the subject matter. Therefore, smaller units' Understanding Goals should connect to the Overarching Understanding Goals or Throughlines. To this end, instructors can use the Throughline questions as parts of assignments, as ways to shape students' work, or as ways to help students reflect on their work. In the DiSEL course, the system development Throughline was "*In what ways are the roles of the project manager, requirements analyst, designer, programmer, knowledge manager, quality assurance specialist, tester and configuration manager interdependent and how do they support the system development process?*" Accordingly, one of the Overarching Understanding Goals was "*Students will understand the different and necessary roles involved in system development.*" Such an Understanding Goal indicates for students what is important to understand and how they should approach their learning.

How students are expected to demonstrate their understanding should be outlined for them by the instructor(s) in the TFU worksheet under "Performances of Understanding." These are the activities students participate in that require them to demonstrate their learning of the

Understanding Goals. Once these performances are clearly explained, assessing student work becomes more straightforward as students can discern for themselves whether they are generally meeting the performance criteria or not.

Performances of Understanding are usually developed by finishing the statement: "Students will build toward achieving the Understanding Goals by..." When students in the collaborative learning course, for example, built on each other's knowledge and resolved their own conflicts, they need to demonstrate collaboration, and this is in fact an expected Performance of Understanding. Accordingly, one of the DiSEL Throughlines is, "In what ways can you collaborate and determine if your collaborations with colleagues are successful or unsuccessful?" and an Understanding Goal is "Students will understand how to define when a group is working and when it is not." As shown here, all of the TFU categories should support one another and reinforce the focus of the course.

Finally, considering how students will get feedback on their performances and by what criteria they are being assessed is the Ongoing Learning Assessment aspect of the TFU framework. Assessments should be happening *continuously* from peers, instructors, and the students themselves, not only about the learning behavior, learning process, learning effectiveness and results of individual and team, and efficiency of collaboration, but also about the infrastructures, facilitators and technologies used to assist the collaborative learning. To define how assessment will happen for students, it is useful to answer statements such as "Students will get feedback on their performances by..." and "The criteria for each performance will be...." By focusing on these two aspects of the students' learning experience, instructors can evaluate their feedback procedure as well as the frequency of their feedback, and reconsider how meaningful their assignments are in the first place. Instructors should not stop there, though. According to Theory One (TO), instructors also need to provide meaningful feedback that helps students build on their ideas so they can take their knowledge to a higher, more flexible level of understanding and improve the virtual collaborative learning infrastructure and technology used. TO therefore enrich the TFU theory and pushes educators to further reflect on their teaching and its impact on students.

"Clear information," "thoughtful practice," and "student motivations to learn" (Perkins, 1995), the other three parts of the TO framework, also complement the TFU framework. "Clear information" means that students should be well aware of what they are going to learn and how they are going to learn. An instructor should articulate these aspects of the learning experience when he or she defines the Understanding Goals and Performances of Understanding within the

TFU framework. Next, the TO framework stresses that students should be given opportunities to use new knowledge thoughtfully, in activities that require application of the ideas taught so that they "engage actively and reflectively with whatever is to be learned" (Perkins, 1995). Performances of Understanding should provide such experiences and feedback should help students reflect on their learning experience. Finally, TO stresses that motivation can be either intrinsic or extrinsic and is critical to the learning process. So, as students proceed with their work, their activities should be "amply rewarded, either because they are very interesting and engaging in themselves or because they feed into other achievements that concerns the learner" (Perkins, 1995).

Both TFU and TO stress that instructors should organize their teaching objectives clearly and share these with students. To do this in the DiSEL course, the instructors created an Expectations Rubric (See Appendix 1) and handed it out within the first week of class. The Expectations Rubric clearly defined for students what was expected of their work throughout the course by identifying the learning categories the instructors planned to address, articulating the Understanding Goals, explaining the expected Performances of Understanding, and specifying the methods of Ongoing Assessment. This rubric was critical in the DiSEL implementation as it provided students with a type of job description such that they would receive in a real work environment. The teaching objectives, understanding goals and the common line of reasoning will be controlled and maintained by the various Ongoing Assessments throughout the learning and working process.

By incorporating the TFU and TO frameworks via the Expectations Rubric, the DiSEL instructors could focus attention on what students do to learn as well as how they will be assessed. This is possible as both frameworks ask instructors to think about active, performance-based, hands-on learning that keeps learners motivated and engaged in the process of learning itself. One way to create such an environment in practice is to incorporate a project for the students to work on throughout a course. Project-Based Learning stresses that by keeping students focused on a project, they can best construct their own understanding of how to accomplish a given or self-defined goal.

Table 2-2: Theory One (adapted from Perkins, 1995)

Theory One	Criteria of Theory One Components	Theory One Implemented in the Collaborative Learning (DiSEL) Curriculum
Clear Information	Descriptions and examples of the goals, knowledge needed, and the performances expected.	The Expectations Rubric is provided to students at the beginning of the course.
Thoughtful Practice	Opportunity for learners to engage actively and reflectively with whatever is to be learned (i.e., tracking different versions of reports to understand the complexity of document repositories).	The DiSEL students are engaged in the system development project as well as in entrepreneurial competitions. Different assessments are carried out to monitor and track the think process and guide student to develop at different phases.
Informative Feedback	Clear, thorough counsel to learners about their performances, helping them to proceed more effectively.	The DiSEL instructors meet with students weekly to review work-in-progress. Students are evaluated by self-assessment and peer assessment; instructors and infrastructure are assessed by leader assessment and facilitator assessment. Learning journals are used for the students to reflect deeper thinking and learning feedbacks.
Strong Intrinsic or Extrinsic Motivation	Activities that are amply rewarded, either because they are very interesting and engaging in themselves or because they feed into other achievements that concerns the learner.	Students participating in the DiSEL Lab have a great deal of autonomy on their project. Further, they are encouraged to select their own project goals and develop business plan for the real market with project outcomes. Out-of-class assessment by prospective employers and entrepreneurial competitions also help to motivate students.

2.2.2 Project-Based Distributed Collaborative Learning

To enable the simulation of "Real World" project-based, collaborative learning for distributed team, the Distributed Collaborative Learning and Assessment Framework and computer-supported virtual environment integrate Project-Based Learning, Collaborative Learning and Distributed Learning into a comprehensive learning context, in which all the collaborative learning assessments are being carried out, and which has following characteristics:

Project-Based Learning

- (Re) Construct knowledge and enhance understanding based on problems and projects
- Simulate "Real World" contexts to develop skills required for working
- Involve "Real World" situations and conversations

Distributed (Distance) Learning

- Learners and instructors separated physically or virtually
- Diversity in background, culture, across physical locations and time zones
- Require (a) synchronous communication systems and interaction techniques

Collaborative Learning

- Encourage teamwork over individual or isolated attempts
- Accomplish conceptual or complicated tasks and common academic goal
- Diversity in knowledge, skills, expertise and performance level
- Integrate communication, knowledge exchange and teamwork for project
- Share process of constructing ideas and heighten student motivation
- Responsible for one another's learning and overall learning effectiveness

2.2.3 Cognitive Learning

Cognitive Learning (Metacognition), or thinking about one's own thought-processes, requires higher-order knowledge, "knowledge about how to get knowledge and understanding" (Perkins, 1995), it evolve the teaching and learning into a higher educational level.

In the collaborative learning course cognitive learning helps students move from doing to reflecting — The instructors wanted students to reflect on their work to better understand their knowledge and where it was applicable to the system development process. Further, students who make reflection a part of their work processes are more likely to take the time to keep a record of their work and this is one of the most important skills the instructors wanted students to learn — Collective Memory. Another benefit of reflection is that students would be less likely to repeat their mistakes as, to a considerable extent, the good thinker in virtually any field has proven to be intellectually self-watchful, self-guiding, and self-assessing.

The Teaching For Understanding framework that drives the course encourages questions of inquiry that are cognitive in nature, such as "How can others best understand your work and the decisions you have made throughout the project?" Students answering these questions in collaborative learning course assignments including journals and a thesis, as well as in discussion, are articulating and sharing knowledge about their work explicitly to each other. This is important in a distributed collaborative learning environment especially as students have no way to assess each other implicitly or through casual observations. Relationships between students living in different places and cultures, and speaking different languages, are difficult to build. By bringing cognitive learning activities into the environment students benefit twofold: by improving their thinking skills and by getting a better sense of each other's strengths and weaknesses.

Thinking skills are a key requirement of Problem-Based Learning (PBL). PBL requires a demonstration of understanding as students must visibly solve problems, and it is this emphasis on the development of problem solving skills that requires reflection on one's thought process. Collaborative student groups need mental management techniques and skills to reach their goals, as they need to be able to explain their thinking to each other. Beyond describing one's thinking, cognitive learning also requires goal setting, strategy selection, and goal evaluation. Typically, cognitive learning skills include the ability to monitor one's own learning behavior, that is, being aware of how problems are analyzed and whether problem-solving results make sense (Bruning et al., 1995). To incorporate mental management into education, Jay, Perkins, and Tishman (1995) suggest that educators should model mental management by:

- Actively monitoring their own thinking processes and remark about them in ways such as, "when I think about this, I first tend to"
- Explaining key mental management concepts and practices
- Developing the habit of discussing and expressing in words their mental processes and by encouraging students to do the same
- Organizing opportunities for student/student and Instructor/student interactions around mental management. For example, students could be asked to diagram and then explain their diagram of the mental path they took in deciding on a solution to a problem.
- Being sure that students get feedback about their mental management practices
- Realizing that each thought process expressed or shared is a teaching opportunity
- Giving plenty of positive reinforcement for effective thinking
- Suggesting and alluding to alternative methods of attacking the problem

When the collaborative learning instructors give feedback to students, these habits of mental management are brought to the fore of the commentary — and they have many opportunities to provide such feedback. Reflection journals and papers, surveys, assessment, peer evaluation and focus group discussions along with the course project are assignments through which the instructors are able to reinforce cognitive learning practices. By asking students to become more aware of their learning, the students theoretically should become more directed, articulate, and motivated in their learning and work. Therefore, Collaborative Learning Assessment, including various aspects of assessment and different assessment techniques becomes one of the indispensable essential constitutions of the Distributed Team Collaborative Learning and

Assessment Framework, which assists Cognitive Learning practices and enhances the educational level.

The Distributed Team Collaborative Learning and Assessment Framework, the implemented prototyping system (CLASS) and DiSEL course, as a lab, put these pedagogical frameworks and theories to the test.

2.3 Barriers for Collaborative Learning Effectiveness and Team Health

Learning and working in a collaborative learning environment with dispersed teams poses problems not usually encountered when people learn individually or groups of people learn and work in the same building. Examples include the constraints (and advantages) of time zones, lack of non-verbal cues, cultural differences between team members and problems of trust and identity. Distributed team members often need to share work-in-progress with others, which may require team members to adopt new attitudes. Developing a team culture and common procedures are essential for the development of credibility and trust among team members in a globally dispersed environment. To be effective distributed teams have to develop new ways of sharing knowledge and understanding in the digital space, and new ways to evaluate the performance of individual or team to maintain team health. Instead of living in the physical space and place, and overcoming distance by transportation, organizations and individuals now have to deal with different combinations of physical and digital spaces and places. These spaces and places can co-exist with one another and can be integrated flexibly. The geographical and organizational flexibility derived from these combinations implies that organizations have to adapt to the new way they manage their internal collaborative learning and working activities and external relations, meanwhile overcome the barriers for effectiveness of collaborative learning and team interaction.

In order to make productive use of the virtual collaborative learning environment and accomplish successful collaborative learning, distributed learning teams need to identify the barriers to effective interaction and collaborative learning in the team interaction space. The effectiveness barriers have been grouped under the heads of individual, team, dispersion, technology and infrastructure and can be summarized as follows:

- Barriers due to Individual
- Barriers due to inadequate Learning Team Organization
- Barriers due to ineffective Collaborative Interaction Processes

- Barriers due to various Individual/Team Dispersion
- Barriers due to incompatible Technology
- Barriers due to insufficient Infrastructure Spatial Setup

Once the instructors and teams know what are the barriers hindering their efforts for learning, they can try to improve their learning activities and interactions. This will allow dispersed team members to identify current problems and obstacles that they face, suggest way/means in which these problems might be handled in a self-sustaining iterative manner.

2.3.1 Barriers due to Individual

Personality - Personality type and temperament has great influence on team communication and relationships in collaborative learning. Understanding and appreciating various personality types can help individuals and teams improve the communication skills and build more effective relationships, discover their patterns of behavior, create and interpret a team's profile, and design performance improvement strategies customized to the team collaborative learning. Addressing interactions between teams, both within and between organizations, and the special dynamics of globally dispersed teams, Nash (1999) defines five critical characteristics essential to effectiveness strategy, clear roles and responsibilities, open communication lines, rapid response to change and effective leadership, and details how each is influenced by the personality types and temperaments of the team members as individuals.

Cultural Background - Dispersed teams/classes include team members with different backgrounds, histories and cultures. Perhaps the greatest obstacle facing distributed teams in collaborative learning is an inadequate understanding of team members "cultural" differences; this is an extreme problem for globally distributed learning teams whose members hail from different parts of the world, with different backgrounds, histories and cultures. Dispersed team members usually work, learn and communicate under a time constraint and the unawareness of different cultures can be the cause of a lot of angst and miscommunication. However, the diversity of cultures can be a source of competitive advantage, provided the team knows how to use cultural differences to create synergy. The most important aspect of understanding and working with cultural differences is to create a team culture in which problems can be surfaced and differences discussed in a healthy manner.

Hofstede's (1991) dimensions of culture are:

- Power Distance: Extent to which members accept that power is unequally distributed

- Uncertainty Avoidance: Degree to which people feel threatened by ambiguity
- Individualism/Collectivism: Primary concern being the individual or the group
- Masculinity/Femininity: Visible success (money & power) versus "caring values" such as sharing and group success

It is very important for the dispersed team of distance learning and the larger organization to rise above the different cultural dimensions and believe/trust in a team/organizational culture, which precedes all of them. Distributed teams usually work under a time constraint and thus the awareness of different cultures is essential as it can be the cause of a lot of angst and miscommunication. The interactions in the Distributed Team Interaction space helps in solving cultural issues by:

- Development of team norms for interaction.
- Development of a team culture different from national cultures and unique to the team which helps propagate understanding amongst team members from different cultural backgrounds.
- Cultural exercises to come at an appreciation of the varied thinking/perception of people from different cultural backgrounds.
- Team member competencies usually include an ability to work across cross-cultural boundaries.
- Establishment of team processes ensuring role and goal clarity and understanding in terms of expectations from team members irrespective of cultural differences.

Identity - Identity plays a critical role in communication where knowing the identity of those with whom you communicate is essential for understanding team interactions in collaborative learning. Yet, when team members are separated by spatial and temporal borders, identity is ambiguous. Many of the basic cues about personality and social roles that people are accustomed to in the physical world are absent in the virtual collaborative learning environment. In the physical world, there is an inherent unity to the self. The body provides a convenient definition of identity: the norm is one body, one identity. Though the self may be complex and variable over time, the body provides a stabilizing anchor. The globally distributed learning world is different. It is composed of information rather than matter. Information spreads and diffuses; there is no law of the conservation of information. The inhabitants of the electronic space are diffuse and free from the body's unifying anchor. One may have many electronic roles in different learning team for different projects. Thus, the virtual collaborative learning environment should manage and maintain the hierarchical identification directory for all the individuals who have different roles and responsibilities with different privileges in different learning circumstances during collaboration.

Trust -The management of a dispersed teams/classes and participants in the distributed learning and collaborative learning environment cannot be conceived and the project cannot be accomplished successfully without trust. The process in which virtual learning team members identify with each other, communicate and share knowledge are related to how much they trust each other and thus is an integral aspect of being a virtual team member. Effective use of the team interaction process also includes having a trusting relationship between team members, which enables collaboration, sometimes even in the absence of clear information available to all. Trust is a critical structural characteristic, which influences the team's success, performance and collaboration. In the collaborative learning environment, virtual teams are often very short-lived and have such characteristics:

- Temporal and short-lived teams
- Membership in multiple teams
- Slow rate of task and social information exchange
- Lack of information identifying motives and values
- Less emphasis on well-defined roles within the team

Hence, establishing trust immediately becomes enormously important (Lipnack, 1997).

Jarvenpaa et al. (1998a) observed that those teams that were not focused on a task reported low levels of trust, but recognized that task focus existed in parallel with a social focus. They also highlighted the importance of the first "online-impression", because the first messages of the team members appeared to set the tone for how the team interrelated. Greater trust was developed at the early stages of globally dispersed teams through a balanced mix of social and task communication, enthusiasm, optimism and initiative. In the longer term, trust was greater in teams that developed set patterns of communication and responded promptly to other team members. The key point is not that different forms of trust exist, but the observation that face-to-face interactions in physical space foster social-based trust that carries into the collaborative learning digital space. To summarize, the important trust-enabling factors in the distributed learning team context are: performance/competence, integrity and concern for the well being of other team members. Table adapted from (Lipnack & Stamps 97), summarizes the trust factors and suggestions for physically or virtually dispersed teams.

Table 2-3: Suggestions for building trust (Lipnack,'97; Haywood,'97)

	Trust Factors	Examples
PERFORMANCE AND COMPETENCE	Develop and display competence	Focus on individual and team results Acquire new skills keeping in sync with new trends Allow others to be experts Foster expertise and share learning.
	Follow through on commitments and show results	Keep a log of commitments and make them visible to teammates. Keep commitments in cost, schedule and technical areas even if situations change.
INTEGRITY	Consistency in speech and action	Align your behavior in meetings, reviews and at other critical times.
	Stand up for your convictions	Be able to say "I don't agree" even in disagreeable situations. Continue to do the right thing even in crisis situations.
	Stand up for the team	Keep up-to-date to prevent having to defend the team. Don' say negative things about the team unless you are sure about the reasons.
	Communicate and keep everybody informed about progress	Hold regular audio/video conferences and have agenda covering both bad as well as good news.
	Show both sides of issues	Present both pros and cons of issues. Start discussion forums to debate issues.
CONCERN FOR OTHERS' WELL BEING	Help team members during transitions	Rotate both "good" and "bad" jobs. Have uniform processes for selection, rewards and sharing of information
	Be aware of your impact on others	Take your role seriously. Take time to develop interpersonal contacts with team members. Ask others how they perceive your reliability in crisis situations and remedy possible faults objectively.
	Integrate personal, local, team and organizational needs.	Map your decisions on other functional areas so as to reduce the impact of adverse actions in team situations on other spheres of work life.

2.3.2 Barriers due to Learning Team Organization and Interaction Processes

Distributed team organizational processes form just one of the three critical aspects of having an effective interaction space for virtual teams during collaborative learning. The manner in which virtual teams and indeed their parent teams implement their team learning/interaction organizations and processes are critical to the success.

Once the standard processes are determined, individual team members are expected to facilitate the implementation of those processes within their local sites. As such, team members must take the viewpoint of their home location as they move into the global team and, similarly, carry the viewpoint of the global team back to their local sites. Distributed teams may define their team needs and learning goals correctly from an organizational perspective, use established team norms and communication protocols, but the application of best practices around team processes and collaboration practices are insufficient if the natural tension between global and local priorities is ignored.

The effectiveness barriers that a team faces in the team organization and processes domain are usually a subset or a combination of the barriers enumerated:

- Language barriers
- Cultural barriers
- Distance barriers
- Insufficient team member motivation
- Ineffective organizational information flow
- Improper group composition and lack of complementing competencies and inadequate combined skill set.
- Insufficient role and goal clarity and definition
- Ineffective task control
- Lack of instructor/TA support
- Lack of group norms
- Lack of trust
- Inadequate size of team
- Reconciliation of quantity of work versus the quality of output from team members
- Congruency between personal and team evaluation of work both formal and informal
- Lack of structured and agile decision-making

2.3.3 Barriers due to Diversity and Dispersion

The diversity of the collaborative learning team members and dispersion issues mentioned related to bridging temporal, cultural, organizational barriers that are to be considered when a change from a "individual" to a "collaborative" and from a "local" to a "distributed" learning environment is effected might make the process of collaboration complex and difficult to manage, especially when organizational processes are tied to a local perspective with different time zones.

The team of collaborative team learning is formed with individuals from various backgrounds who have diversity in different aspects:

- Diversity in Knowledge and Skill Sets
- Diversity in Expertise and Performance level
- Diversity in Responsibility and Privilege
- Diversity in Background, Culture and Language
- Diversity in Physical Location and Time Zone

Although, the diversity of individuals can be a source of competitive advantage, provided the team knows how to use cultural and background differences to create synergy, it increases the complexity and challenge for effective interaction and collaboration in the collaborative learning environment. The most important aspect of understanding and working with differences is to create a team culture in which problems can be surfaced and differences discussed in a healthy manner.

It should be noted that working in teams that span the globe poses problems not usually encountered when a group of people work together in the same building. An important dimension of distribution and globalization has been the standardization of time in work and social life. By changing the nature of the friction of distance, the question of time and its significance in work and everyday life has been reopened. If members of global teams work in different time zones, then responses to queries or requests for information needed to get on with a task will be delayed. And if team members in Asia are 12 hours ahead of those in North America, they will have less overlap with work hours, thereby reducing the opportunity to call one another during normal business hours.

Therefore, in the virtual collaborative learning environment asynchronous communication and collaboration solutions have to be integrated to overcome the barriers of geographical and time zone diversity.

2.3.4 Barriers due to Technology

Since dispersed learning team members typically use advanced communication technologies, it is especially important to examine technology barriers and their impact on the spectrum of interactions, interaction quality and practices, information exchange and team outcomes. Barriers to collaborative interaction space effectiveness due to technology can be considered as two categories:

1. Lack of team consensus on the use of communication technologies

   In the absence of an agreement or discussion for how to use the different technologies, team members will eventually end up using different tools to accomplish the same task. From a coordination mechanism perspective, the globally dispersed team has the necessary technologies at its disposal, but no agreed upon procedures for how to use the technologies, and no explicit procedures or conventions for this were developed.

2. Asymmetry of ability to use the technologies

   In the absence of procedures for how to use the technologies, the use of technologies for interacting with global team members is most often than not dependent upon the team members' own prior skills. However, this can sometimes lead to extra work in the case of global distributed teams. For example, consider two team members putting a lot of effort into using a message board for two-way communication while a third team member using E-mail to convey ideas to the group since the member is not aware of the procedure for using the message board. This shows an asymmetry of ability to use the technologies. Each team member developed his or her own personal style of working with the technology.

The some of the effectiveness barriers that a team faces in technology domain have been identified as below. However, it is quite possible that specific teams face additional barriers not enumerated here. Virtual team members can use this to identity the set of effectiveness barriers applicable to their own global team.

- Inadequate technical accessibility
- Inadequate technical expertise

- Insufficient protocols for use of communication channels
- Power/functionality offered by technical resources
- Lack of commonly available technical resources
- Insufficient expertise of using shared resources
- Inadequate use of technical facilities
- Insufficiency of information notification system
- Inadequacy of technical training
- Language/cultural influence in interpreting information coming through information channels
- Ease of use of technical facilities
- Reliability of technologies used
- Speed of communication
- Inadequate functional ability
- Inadequate reliability

2.3.5 Barriers due to Infrastructure

The convergence of computing and telecommunications has led to core activities being reorganized around information. An essential aspect of dispersed learning teams is their ability to exploit the features of this new virtual interaction space. Therefore, the locational patterns of the networked information cannot truly represent the geographical patterns of its use. With the rapid development and proliferation of communication technologies, comprehensive collaborative learning organization increasingly have to operate in two spaces simultaneously - the physical space and the electronic virtual space. These two spaces are not mutually exclusive and they sometimes overlap with each other. However, many of the rules governing these two spaces are fundamentally different. To survive in the information economy distributed classes must not only exploit geographical differences and overcome geographical constraints in the physical world, but they also have to exploit opportunities and face threats in the new electronic space. Our notion of time is significantly affected by the emergence of the computer-supported virtual collaborative learning space.

With the emergence of the digital virtual learning space, the nature and characteristics of the physical space has been radically redefined. This is not to say that the physical place is no longer relevant to individuals, teams and organizations. On the contrary, local characteristics will continue to affect the effectiveness of interactions between team members from different places, even in the globally dispersed place. Indeed, although in the electronic space the friction of distance has been eroded, other frictions of distance derived from differences between places (e.g. local culture and language) will continue to work. The effectiveness barriers that a team faces in spatial setup domain are usually a subset or a combination of the barriers enumerated below:

Physical Space

- Dissatisfaction with the current setup of chairs, tables, cameras, and computer/TV screens at primary location
- Dissatisfaction with the current setup of chairs, tables, cameras, and computer/TV screens at remote locations
- Physical setup creates the feeling that remote team members are mere observers in the interaction
- Improper meeting room layout
- Inadequate resources - lights, microphones, screens, speakers
- Improper positioning of technical resources
- Meeting room capabilities are asymmetric at different sites
- Meeting rooms are not accessible
- Inadequate skills of members to use the infrastructure for better use of physical space

Digital Space

- Inadequate utilization of online resources
- Online resources are not readily accessible from multiple locations (for example, office, cubicles, meeting rooms, home, airport).
- Insufficient technological reliability, ease of use, excessive response time to access online resources
- Inadequate technical training of team members to use the online resources

- Improper layout of the digital space making it difficult to access the information
- Improper mobilization of team web site or common web repository
- Inadequate usage of digital resources for meetings

2.3.6 Overcoming the Barriers

It will be a significant challenge for the distributed collaborative learning teams to exploit the collaborative learning and interaction space by overcoming the barriers identified in this chapter. The Collaborative Learning and Assessment Framework developed in next chapters merged the physical space with the digital space to make some inroads in tackling the complexities and barriers facing dispersed learning teams. The emergent digital virtual collaborative learning space increases the complexity of the project-based distance learning environment and the geographical flexibility of organizations. Globally dispersed learning teams therefore must be seen in this broader context of the learning and interaction space and their effectiveness must be evaluated in a systemic manner involving the virtual learning environment. Moreover, some suggestions on overcoming the barriers based on past research have been provided:

1. Engage the team in setting expectations about behavior and performance and record the team's decisions and commitments to each other.
2. Determine, as a team, how conflict will be addressed and resolved.
3. Clearly define member responsibilities (Jarvenpaa et al. 1998a).
4. Use rigorous project management disciplines to ensure clarity (Gerber 1995).
5. Proactive behavior, empathetic task communication, positive tone, rotating leadership, task goal clarity, role division, time management, and frequent interaction with acknowledged and detailed responses to prior messages (Jarvenpaaet al. 1998b).
6. Strive for a good faith effort in complying with the team norms and commitments, be honest in team negotiations, and don't take advantage of others or of the situation (Jarvenpaa & Ives 1994).
7. Encourage social communication that accompanies task completion.
8. Provide more formal communication than in traditional same time/same place team (Gerber 1995).
9. Focus team learning on the tacit as well as the explicit knowledge; document the tacit and embed the process into the organizational structure (Grenier & Metes 1995).

10. Match desired activities with performance evaluation factors; reward the desired performance (Myers & McLean 1995).

11. Design and integrate communication technologies that fit the team environment; don't force the team to adapt its behavior to the "latest" technologies.

12. Provide training support for communication technologies to all team members.

Chapter 3 Distributed Team Virtual Collaborative Learning and Assessment Framework

3.1 Distributed Team Collaborative Learning Environment

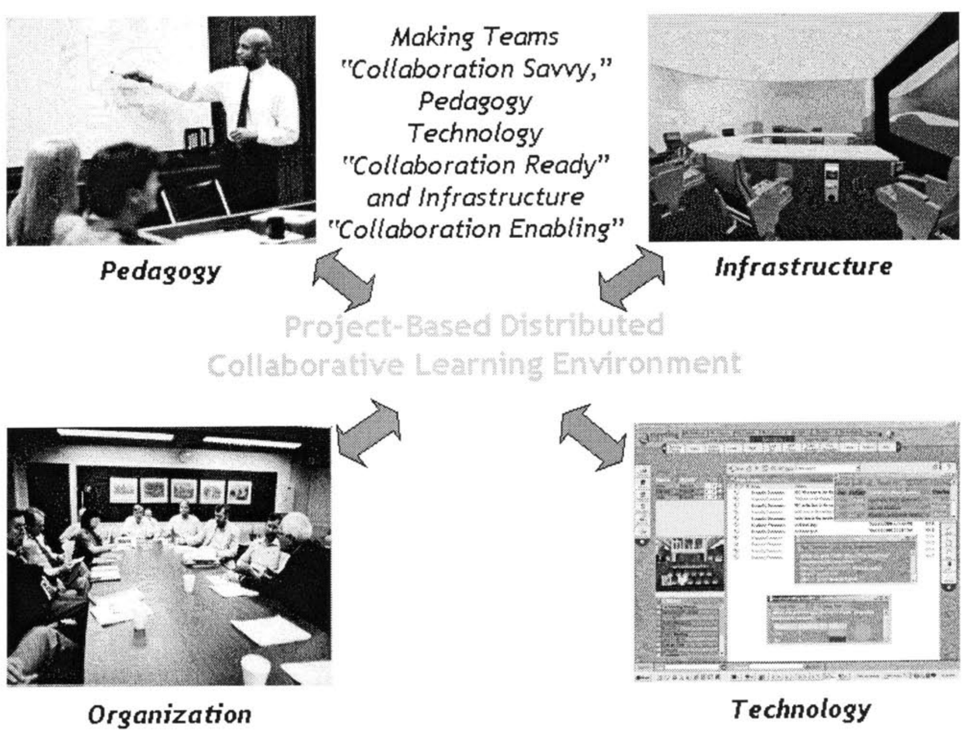


Figure 3-1: Pictorial Representation of Collaborative Learning Environment

Learning is not just an individual behavior to obtain knowledge, but also a combination of interaction, communication, collaboration, collocation and coordination within a social environment. Rapid advances in information and communication technologies have brought about tremendous changes from the traditional learning to collaborative learning for the distributed teams. To realize effective projected-based distributed collaborative learning and overcome the effectiveness barriers, the collaborative learning environment should be constructed based on the pedagogical theories and frameworks, and distributed team learning interaction space with organizational processes, technology support and infrastructure enabler (as shown in Figure 3-1). This environment can be built up from both physical perspective and virtual perspective. Pedagogy, Organization, Technology and Infrastructure form the four dynamic dimensions of collaborative learning environment. These dimensions influence each other, a change in any one of the dimensions requiring a reinforcing change in the others.

The interaction in collaborative learning environment encompasses the following four primary elements:

- Communication involves the exchange of information, events and activities in any dispersed learning team. Effective communication is a necessary, though not a sufficient condition to meaningful collaboration in a global learning team.
- Collaboration describes the process of sustainable value creation that creates a shared understanding within the team.
- Collocation involves dealing with the infrastructure to provide seamless communication among geographically distributed team members.
- Coordination involves control of the workflow and communication process, allowing efficient control mechanisms to coordinate team efforts. Coordination involves managing the various interdependencies between activities and events in any global team.

The challenge of accomplishing learning and project goals and assignments without the advantage of being co-located and being able to meet face-to-face is critical. The advantages of going "virtual" are numerous but for the potential to be achieved, significant challenges and barriers must be addressed. The literature review from Chapter 2 indicates that there are diverse issues related to bridging individual diversity, temporal, cultural, organizational barriers for teams to make a successful change from a "individual" to a "collaborative" and from a "local" to a "distributed" learning environment. This multi-diverse nature of distributed collaborative learning teams makes the process of collaboration complex and difficult to manage. One of the key issues for dispersed learning teams is therefore to set the bounds of their learning interaction space (Vadhavkar & Peña-Mora 2000). To effectively use this interaction space, the individual components, which make up this space, must be identified and their importance to the interaction process understood.

3.2 Dimensions of Learning Team Interaction and Collaboration Space

For globally dispersed learning teams, this boundary or interaction space for virtual learning teams is made up of three components as shown in Figure 3-2, which can be considered to be the effectiveness foundations or dimensions of distributed team learning interaction.

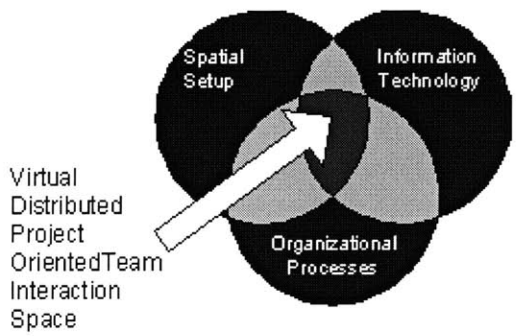


Figure 3-2: Distributed Learning Team Interaction and Collaboration Space

- **Organizational Processes** – trust building, team culture, learning and meeting processes, team processes and team members' behavior
- **Communication Technology** – audio/video conferencing systems and computer supported communication processes
- **Spatial Setup**
  - Physical space - meeting room layout, office environment, computer/TV positioning, screen layout, placement of audio and video equipment, placement of chairs.
  - Digital Space - web-based team interaction spaces such as collaborative application spaces, team websites, central repositories, and data conferencing servers.

In the collaborative learning process, the **Pedagogical Frameworks** developed in Chapter 2 will guide and influence the components of the interaction space to overcome various barriers of distributed learning team for an effective collaborative learning. And combined with other three dimensions of interaction and collaboration space, these essential components act as the four dynamic dimensions of collaborative learning environment.

3.2.1 Organizational Processes

For most global teams, effectiveness barriers crop up because of incorrect usage of the facilities that are being used to facilitate the interaction process. Organizational processes and interaction space protocols help facilitate the team interaction process by prescribing processes to leverage the communication infrastructure to eliminate or marginalize effectiveness barriers. The processes and protocols potentially serve as:

- Facilitators of the team interaction and learning process
- Support systems for the development of trust and team culture
- Mechanisms for storing:
  - Group memory
  - Interaction history
  - Decision
  - Team collaborative learning

Most communication theories propose that conflict in teams is the result of poor communication in quality, quantity or form. The theory postulates that if quality of the information exchanged can be improved, the right quantity of the communication be attained, the causes of the dispute will be addressed and the team members will move toward resolution. To address the needs for conflict resolutions in teams, McGrath (1964) has defined a framework based on the modes of the processes that teams engage in:

1. Mode I: Inception and acceptance of a learning objective or project (goal choice)
2. Mode II: Solution of technical issues (means choice)
3. Mode III: Resolution of conflict (policy choice)
4. Mode IV: Execution of the performance requirements of the project (goal attainment)

Implementation methodologies link modes together in a systematic manner through defining and structuring the activities within each mode based on the pedagogical framework guidance. Most attention has been focused on Mode II, in the form of problem solving and decision making research. Computer-supported interactions simplify the handling of information; organize group processes and procedures that enable the team to deal with internal team dynamics. Formalizing group learning and interaction processes is critical to improving team interactions and increasing team performance.

3.2.2 Information Technology

Technology is one of the key components of the team learning interaction space, especially for the virtual collaborative learning environment. It is extremely important to ensure that the technology component is well addressed in virtual teams because communication is the means of creating synergy in virtual teams and technology enables communication. Keeping geographically dispersed team members on the same page is a difficult task and without a comprehensive technology infrastructure to facilitate the communication processes virtual teams veritably ensure their failure.

Multiple types of technologies are used to keep the team together and in alignment. Teams communicate regularly by telephone, fax, videoconferencing, shared databases, web sites and a myriad of technologies. The most important issues that relate to the use of communication technology and communication in general can be summarized as (Sen 2001):

- Use technology you need to use
- Use technology you know how to use and are comfortable with
- Use technology you perceive as fastest relative to what you want to achieve
- Use technology that works
- Do not assume that others think like you on these issues

The term **computer-supported collaboration technology** describes the entire category of electronic options available to a distributed virtual team. It is a very broad term covering the spectrum of electronic systems that integrate software and hardware to enable communication and collaborative work. Such technologies can be broadly classified into two main categories:

- Asynchronous
    - E-mail

- Group calendars and schedules
- Bulletin boards and websites
- Non-real-time database sharing and conferencing
- Work-flow applications

- Synchronous
  - Desktop and real-time data and application conferencing
  - Real time application interaction
  - Electronic meeting systems
  - Video conferencing
  - Audio conferencing

The different synchronous and asynchronous technologies mentioned above all have their advantages and disadvantages and no particular technology can be described as the one ideal for having an effective interaction space. Which technology will be used should depend on the needs and capabilities of the distributed learning team, the collaboration process and conditions of the infrastructure.

3.2.3 Infrastructure and Spatial Setup

The infrastructure and spatial setup of a globally dispersed team is one of the key components of its learning team interaction space. More often than not, virtual teams do not pay attention to using its spatial setup effectively. The day-to-day working environment of global team members is highly determined by the physical, architectural space around. This physical space also constitutes a rich information space either as direct information sources (for example, calendars, maps, charts hanging on the walls, books and memos lying on the desks), or by providing ambient peripheral information (for example, sounds of people passing by). However, with the advent of information age, more of this information has become available to team members in the digital space (for example, project web sites, discussion boards, web-based calendars). Geibler & Holmer (1998) considers the spatial setup to be made up of:

- **Cognitive space** of the individual processing content in order to solve the tasks
- **Social space** reflecting working practices and organizational context
- **Physical space** including the architectural components of the building, the room and the surroundings
- **Information space** provided and mediated by networked information devices providing the functionality needed for working on the task.

To enable efficient collaboration and to provide support for a globally distributed learning team, both the aspects of spatial setup mentioned above need equal attention. Spatial setup for a globally dispersed team can be broadly subdivided into:

Physical Space - meeting room layout, office environment, computer/TV positioning, screen layout, placement of audio and video equipment, placement of chairs

Digital Space - web-based Virtual Collaborative Learning Environment such as distributed team interaction space, team collaboration space, collaborative application spaces, team web sites, central repositories, and data conferencing servers

3.3 Framework Overview

Collaborative learning in curricular teaching and organizational training environment as preparation for education, engineering and research are being revolutionized by the progress in computer-supported collaborative environments. Computer-supported network-based Virtual Collaborative Learning and Assessment Environment results in more effective and economical team efforts among locally or geographically distributed team participants. Distributed data, distributed application, distributed participants and distributed management have to be brought together into an electronic virtual learning and interaction space, which is shared by participants with possibly different nationality, cultural background and expertise, for the same goal but from any place, at any time in any virtual teams.

Based on the pedagogical frameworks and theories stated in Chapter 2 and the four basic dynamic dimensions of collaborative learning and interaction space, a Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) was built up through the research as a guideline to support the design of computer-supported collaborative learning environment (shown as Figure 3-3).

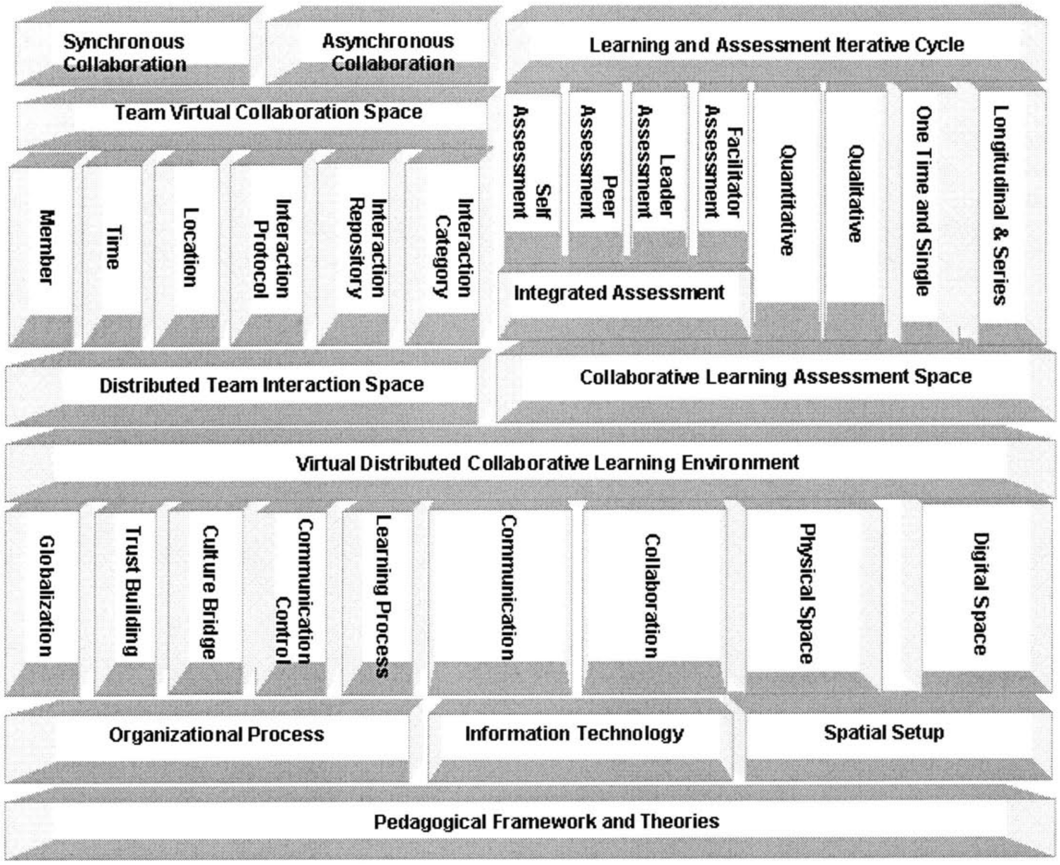


Figure 3-3: Distributed Team Virtual Collaborative Learning and Assessment Framework

Most of the traditional collaboration environments or electric learning systems focus on the communication and information sharing, whereas this framework emphasize particularly on

- How to control the interaction protocols and processes,
- How to deal with learning teams internal dynamics,
- How to realize distributed information and application sharing,
- How to process problem solving and decision making through collaboration,
- How to assess and improve the effectiveness of collaborative learning and team interaction,
- How to keep common learning focus and enhance team performance,
- How to maintain the health of team cooperation and development,

While stressing and overcoming the identified learning effectiveness barriers throughout the collaborative learning process.

The DTVCLA framework captures the key dynamic dimensions and reflects the iterative nature of collaborative learning process: from carrying out learning interactions and collaborations in the physical and digital space (the distributed team interaction space and team virtual collaboration space); to observing the barriers to effective learning and interaction by evaluating the effectiveness variables in the collaborative learning environment; to mapping individual and team performance to Collaborative Learning Team Effectiveness Continuum and comparing them with the desired effectiveness state; to identifying areas of improvement and making adjustments to remove these barriers in order to increase the learning effectiveness and maintain the team health.

The Distributed Team Virtual Collaborative Learning Environment encompasses three major spaces (models): Distributed Team Interaction (DTI) Space, Team Virtual Collaboration (TVC) Space and Collaborative Learning Assessment (CLA) Space. All these spaces are supported by the developed underlying four dimensions (Pedagogical Framework, Organizational Process, Information Technology and Spatial Setup) of collaborative learning environment, among which the pedagogical frameworks and educational theories adopted in this research will guide and influence all other dimensions and activities for collaborative learning. This thesis will emphasize on the Collaborative Learning Assessment Space and models described in the next several chapters, and the first two spaces are analyzed in the following sections of this chapter.

This framework based on the virtual team interaction framework (Peña-Mora, 1999; Peña-Mora 2000) also captures the iterative nature of the collaborative learning and interaction process. Thus, it can be said that this framework represents the collaborative learning and assessment iterative cycle in which distributed learning teams function.

- Identify barriers to team collaborative learning and interaction effectiveness through observation of the interactions carried out in the interaction space and learning performance
- Position the team in the team interaction space effectiveness continuum
- Evaluate the revised team learning and interaction effectiveness targets after positioning the team on the team interaction space effectiveness continuum
- Enhance/provide goals for further learning and interaction in the collaborative learning environment

Based on this framework, the design of Virtual Collaborative Learning Environment will bring more value and advantages to the traditional distributed collaborative learning:

- Result in educational/organizational reengineering accompanied by an equally radical change in information and communication technologies
- Guide, monitor and control the behavior of the participants in the learning/interaction processes and maintain the common goal and focus of the class
- Allow teams/participants to collaborate conveniently both in synchronous and asynchronous way to be effectively reconstituted from formerly dispersed members across the globe and enable applications and data accessible from anywhere, any time in the world
- Realize the competitive synergy of teamwork and exploiting the burgeoning revolution in telecommunication and information technology
- Guide Individual Learning at a level-appropriate pace in different phases to achieve understanding of learning goal
- Conduct cognitive learning practices and knowledge management to evolve the educational level
- Evaluate and improve team/member's performance, effectiveness and efficiency of collaborative learning and interaction

3.4 Distributed Team Interaction (DTI) Model

With the knowledge about the dynamic dimensions of Team Interaction Space stated in previous section, a Distributed Team Interaction Model for effective collaborative learning and collaboration has been analyzed.

3.4.1 Team Interaction Modalities

The distributed nature of distance learning teams imposes a major constraint on team interaction. Interaction is discussed in this context based on the group activity it supports and its modality. It is critical in analyzing the various forms of interaction to make a clear distinction between acquiring information and developing knowledge. The two concepts are linked yet require distinct modalities of interaction to achieve the appropriate purpose of the communication.

Team activities engender different modes of interaction within the learning team. Understanding these activities in collaborative learning and the varied modalities they require is a prerequisite to creating an effective interaction space. A classification of interaction needs for globally dispersed teams is presented below (Hussein 1998):

- Information dissemination is transmitting information from one team member to another. The information itself may be in a variety of media formats.
- Knowledge Sharing/Building is the process by which a team leader and team members through discussions achieve a shared understanding of a particular concept. It should be noted that the formal knowledge sharing interactions must necessarily be supported by the other interactions discussed below in order to make the interaction space more effective.
- Group Cohesion is a prerequisite in supporting distributed learning teams. Interactions among group members that are unintentional and unstructured provide a basis for such cohesion. They are crucial and defining interactions that provide a sense of team and create a shared motivation among members of the team.
- Group coordination interactions are critical in the effective functioning of teams. These include notifications of meetings, agreements and responsibilities. These interaction forms comprise a large percentage of collaborative group interaction.
- Decision-making is another critical class of interaction that provides mechanisms for groups to reach a shared direction, learning goal or vision. These interactions include a large degree of conflict (which is healthy) and provide a critical mechanism for incorporating individual viewpoints within the team.
- "Building Networks" is a broad category of interactions that encompass communications between team members and others outside the boundaries of the team. These interactions may be for the purpose of enlisting support, integrating additional members or seeking expert opinion or information.

The following is a list of the four modes of interaction identified in addition to brief descriptions and examples (Hussein 1998):

- **Synchronous/Asynchronous Interaction:** Interactions can be classified according to the temporal relationship between the information sender and receiver. Synchronous interaction refers to communications that are immediate and whose expected response is immediate. These include face-to-face meetings, instant message, audio calls and videoconference interactions. Asynchronous interaction consists of exchanges of information through multiple media - documents repositories, bulletin board, video or audio clips - i.e. communication that is stored in some form before transmission to the receiver of the information.

- **Structured/Unstructured Interaction:** The degree of structure in an interaction is a more difficult concept to define. Structured interaction involves time critical discussions with explicit or implied agendas and explicit or implied facilitation processes. Unstructured interactions do not have an explicit or implied process associated with them. Examples of structured interactions are board meeting (synchronous) and change orders (asynchronous), while unstructured interactions are characteristic of lunch chats or for-your-information memos.
- **Intentional/Unintentional Interaction:** Intentional interactions are those that are planned beforehand and have an explicit objective. Unintentional interactions occur in coincidental meetings such as coffee breaks or hallway encounters.
- **Committal/Non-committal Interaction:** Interactions are meant to elicit a particular response or state of mind in the sender and receiver. The degree to which an explicit interaction response is expected defines the amount of commitment in the interaction form. The degree of commitment is generally defined by the environment of the interaction.

Information dissemination typically exhibits asynchronous, unstructured, intentional and marginally committal interactions. Knowledge sharing and building, on the other hand, requires dynamic interaction among the team members, which necessitates synchronous, structured, intentional and committal interaction processes. Interactions that are responsible for group cohesion activities are typically unintentional, non-committal and unstructured with varying degrees of synchronicity. Coordinating tasks requires clear definitions of process and hence is generally structured. The coordinating process is also intentional and requires a high degree of commitment from the receiving party. Synchronicity in coordinating process varies with purpose of the coordination activity. Decision making activities also require high degrees of communication among the group members and hence require synchronous, intentional and highly committal interaction. These activities are also typically structured. Finally "Building Networks" can take on any of wide range of modalities depending on the nature of the activity performed by the outside parties to the interaction.

3.4.2 Distributed Team Interaction Model Systems Approach

From a systems approach, the team interaction space can be analyzed by looking at the information protocols and the interaction modality.

Specifically, there are two main information protocols:

- Communication Protocol: A set of rules for information transmission across a medium or a network.
- Interaction Protocol: A set of rules and algorithms that govern the accessibility of other dispersed team members in an interaction. These include rules for proximity, addressability (controls over the ability to interact with others in the interaction environment), privilege and presence in an interaction space.

Communication protocols define and enable the transmission of information from one machine to another through the network. Interaction protocols enforce order on the communication over the networked collaboration by controlling the ability to address particular individuals.

Interaction modality defines the variety of information structures and media available to the interaction.

- These information structures may include audio transmission, video transmission, image transmission, text transmission and structured data (in the form of documents, presentations, spreadsheets, schedules, CAD drawings, formatted text). And the interaction space can be visualized as the individual team member's interface in the virtual collaborative learning environment for distributed team members.
- The interaction modality defines the interaction media, i.e. input and output devices by which information is displayed within each individual's learning interaction environment. The distributed learning team members can access the virtual learning environment from traditional terminals, desktops, laptops, PDAs, other portable computers or even java enabled phones and pagers.

The information protocols and the interaction modality of each virtual collaborative learning environment will depends on the requirement for the learning objectives, the distributed environment, the needs of the team interaction, the technology and infrastructure available for the learning teams.

3.4.3 Virtual Distributed Team Interaction Space

Based on the Distributed Team Interaction (DTI) Model, a web-based distributed team interaction space has been developed to help

- Maintain a common learning goal definition of the distributed team,
- Define common understanding of usage of communication channels,
- Identify individuals, who have different roles and responsibilities with different privileges during the collaboration while building the trust within learning team,
- Have better knowledge of distributed teams and locations, as the system not only provides relevant project information but also personal information of all team participants,
- Cooperate with individuals that deal with multiple projects within multiple sub-teams of collaborative learning located in remote sites,
- Share knowledge, skills and expertise with learning team members and give suggestions for specific issues,
- Record team thinking and working processes - Collective Memory in the information repository.

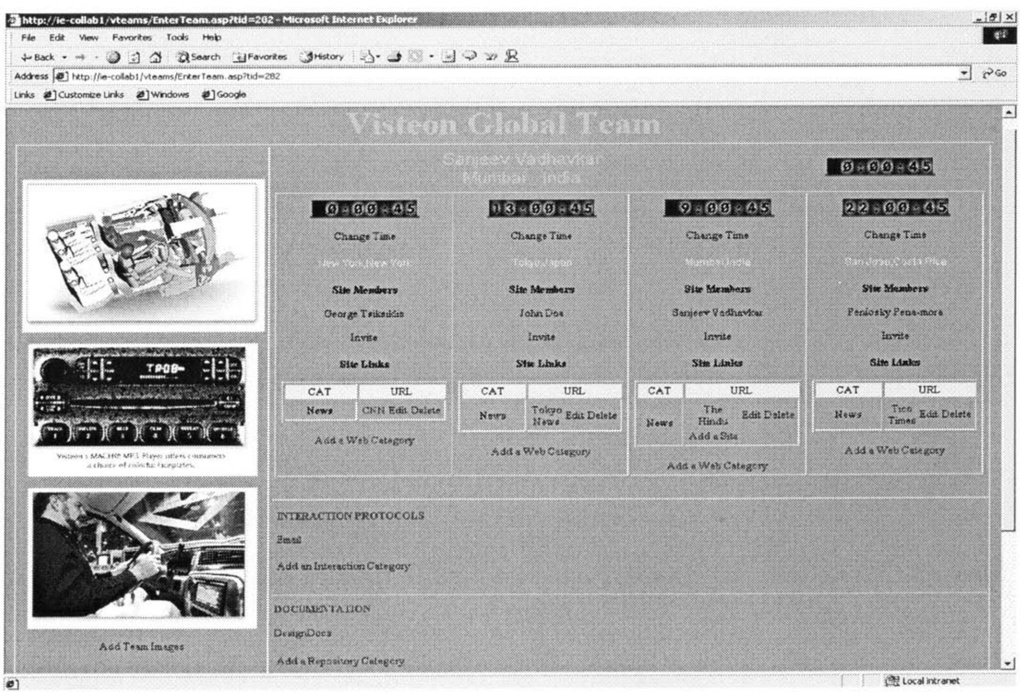


Figure 3-4: Distributed Team Interaction Space

The web-based Distributed Team Interaction (DTI) Space should provide the following information:

- Site List – the names of the dispersed sites where the virtual leaning team members are located.
- Member List – the list of team members sorted by site so that they can be more easily identifiable.
- Time – the times of all the sites where the team has members
- Interaction Protocols – a common contract/ agreement of the team members on a list of communication protocols, which serve as support methodologies as well as active communication channel usage guide to all team members to be respected and followed. The protocols are divided into
    - Issues – a group/collection of issues considered important for consideration of the team members so that they can agree upon how best to coordinate their communication efforts
    - Suggestions – a list of suggestions for the usage of different communication channels is also provided.
    - Agreements – a set of agreements in any of the interaction categories.
- Repository – this team website can also serve as a data repository for the team for all related documents and sharing these documents. The data repository should provide team members to upload and download files, as well as allow them to change the submitted files. The repository should provide a log of such changes committed to submitted files and information pertaining to these changes, notably the person who created the file, the list of people who have actually modified the file and the date and time of the file modification. It should be possible to rollback to previous editions of the same file.
- Information Categories – these include categories like weather and news created by different site members. The different sites can then fill in the details for their local site and thus, the team website would reflect information about the local sites that the sites want to show and which would be reflective of the local site information. These help in relating to remote team members on a personal level and can serve as the basis for personal interaction.

Figure 3-5: Team Site Information

The team site-specific information shown on Figure 3-5 provides:

- The location of the site, city and country
- The local time for that site
- The names of the team members belonging to that site
- The information or web links created by the members of the local site

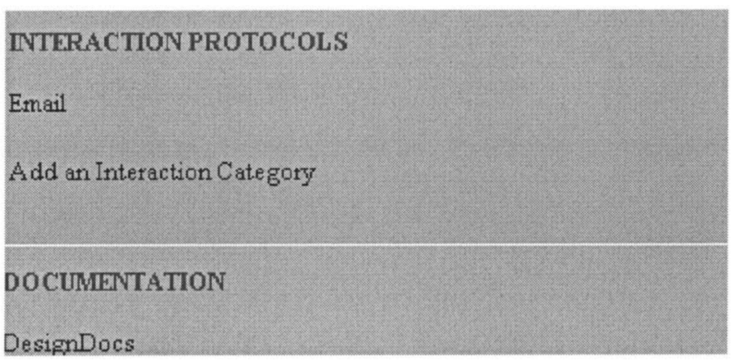


Figure 3-6: Team Interaction Protocols and Repository

The interaction protocols can be followed as a link. The information on the shown information protocol, in this case, is email. For each interaction protocol, the following information is available as following screen dumps.

- Issues that the team has created in that interaction protocol

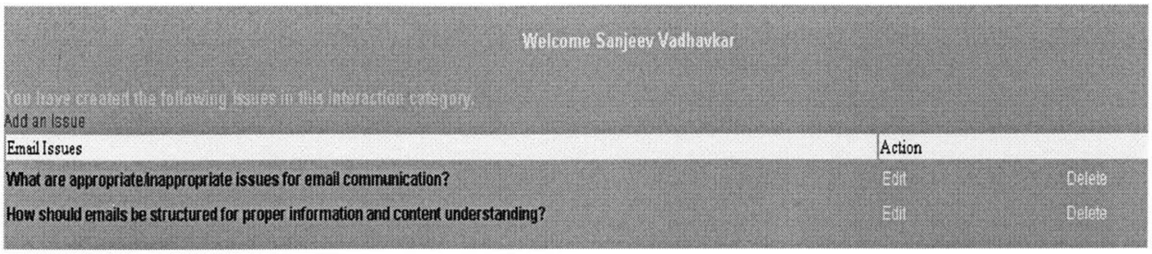


Figure 3-7: Interaction Protocol Issues

- ➢ The suggestions that have been made by different team members about using that interaction medium

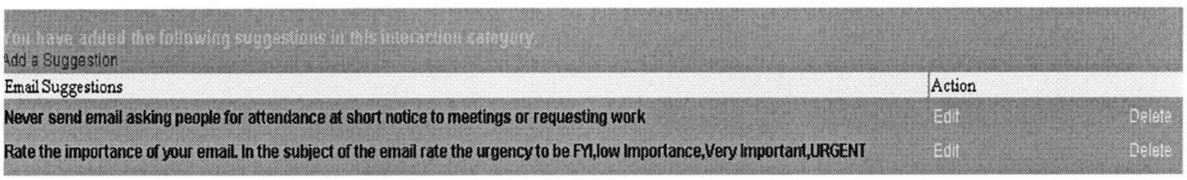


Figure 3-8: Interaction Protocol Suggestions

- ➢ The agreements that the team has reached, as regards using the specific interaction medium

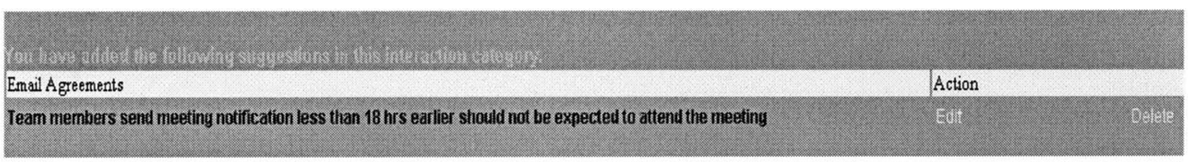


Figure 3-9: Interaction Protocol Agreements

- Interaction Space also needs to have ability to identify team members' roles and responsibilities with different privileges, and to regulate the team member permissions. In this system, there are such different roles during the collaborative learning interaction:
  - ➢ Users – can create information/interaction categories, delete whatever they themselves create. However, they cannot add Agreements in the different interaction protocol categories.
  - ➢ Power users – ability to modify issues and suggestions in interaction categories and information links created in information categories by other users.
  - ➢ Supervisors – can created agreements in different information and interaction categories.
  - ➢ Administrators – ability to modify other user's permissions.
- Permissions to set/change files in the information repositories:

- Authors – can add, edit and delete files
- Replicators – can modify files created by others
- Administrators – can delete files created by others

Therefore, the Distributed Team Interaction (DTI) Model helps to overcome the barriers due to individual diversity and team dispersion, the barriers due to inadequate learning team organization and interaction processes, the barriers due to lack of member identity and team trust, to increase the effectiveness of collaborative learning interaction.

3.5 Team Virtual Collaboration (TVC) Model

To fulfill the tasks and common goals in distributed learning environment, communication and collaboration become the basic requirements for the dispersed learning team members during the collaborative learning process. The research of DaVinci Initiative at MIT has been trying to understand how participants interact in the area of both physical and online meetings. Some general observations of collaborations patterns are identified, among which, the protocols and rules used during a meeting have been the primary research outcomes. Meeting protocols establish how information is shared within the collaboration and how control of the meeting is established. CAIRO (Collaborative **A**gent **I**nteraction and Synch**RO**nization) was developed as a realization of the collaboration research at MIT. Adapting a strong implementation of meeting protocols, CAIRO uses the Internet to communicate in a highly structured environment that includes protocol-enforcing agents to simulate a physical meeting with a facilitator. Team Virtual Collaboration (TVC) Space is an online meeting and collaboration environment that encompasses many of the research results such as membership, information policies and meeting protocol enforcement, besides the synchronous and asynchronous communication capability.

Team Virtual Collaboration (TVC) model are designed to

- Bridge the geographical and temporal barriers of the distributed learning team members,
- Allow teams/participants to communicate conveniently both in synchronous and asynchronous way to be effectively reconstituted from formerly dispersed members across the globe,
- Enable information sharing, data exchange and applications real-time interaction from anywhere, at any time in the world,

- Realize persistence of collaboration data and consistent representation between collaborators of different devices,
- Control the workflow and communication process, allowing efficient control mechanisms to coordinate team efforts for effective problem solving,
- Coordinate all distributed expertise and resources to make decisions; and structure the resulting actions to be taken.

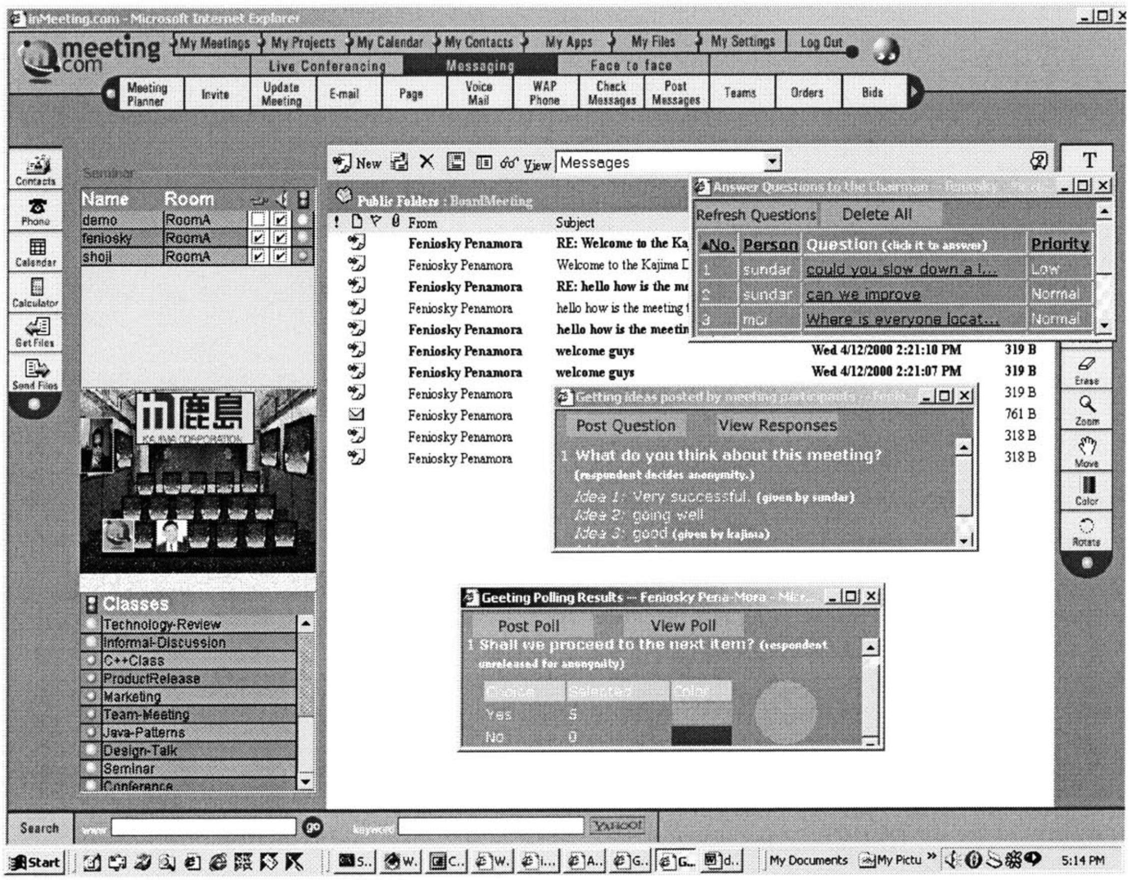


Figure 3-10: Team Virtual Collaboration (TVC) Space

Based on the requirements for the team virtual collaboration environment, the system will need to provide a structured collaborative and meeting environment for each collaborative session and information about current the collaborators. An information policy will be established to determine how information flows during the collaboration for learning and the proper channels for communication. Persistence of collaboration data will be necessary as well as the need for multiple hardware devices to access the virtual collaboration environment. A mechanism for server synchronization is needed to support coordination and synchronization among multiple servers.

Structured Collaborative Environment

The collaborative learning may take place in a distributed computing environment where multiple types of collaborations will take place using various devices at the same time. To solve the problems of confusion and disorganization among collaboration participants in a distributed environment, to help the team to process content sharing, result structuring and decision making and actions taking in a effective collaborative way, the participants are placed in a structured environment where policies can be set and enforced to avoid chaos and/or anarchy. By guiding how the participants interact, the system can help in maintaining control of the collaboration, allowing the leaders of the session to be more effective in coordinating resources.

Collaboration Session

A collaboration session is any grouping of participants for the purpose of working and communicating with one another. Sessions take the form of meetings that involve presentations or intense planning where ideas are developed and explored. The session can last for any length of time and can also be stopped and resumed at a later date if the session has not concluded. Session should also be recorded for documentary purpose, and be able to be played back for various purposes, such as staff training.

Session Organization and Side Sessions

A collaboration session may exist within a complex arrangement of other sessions. Sessions may exist in a hierarchical fashion, resembling an organization structure. Collaboration sessions may spawn side sessions that are separate, with their own rules and resources, but still belong to the main collaboration session and retain some access to its resources.

Conversations and Side Conversations

A conversation is any communication between collaboration participants. The conversation is the channel through which information is conveyed to others. Whispers, or side conversations are a particular kind of conversation that contains only a subset of the participants involved in the entire collaborative effort. Communication between all collaborators will certainly take place, sharing information and directing resources. Additionally, some of the collaborators may have questions concerning an order. These cases can be handled in side conversations, involving only the parties that are necessary.

Meeting Protocols

Protocols are the rules of collaboration sessions, their organization and the conversations within each session. Protocols limit the flow of information, control the number of participants speaking at the same time and maintain a level of control. The protocols of a meeting define the process by which a participant is able to communicate with others often requiring permission of a session leader. Protocols act at all levels, from individual participant requests to side session requests for access to main session information. Protocols are effective in situations involving participants that do not know each other. By forcing the participants to abide by rules, authority can be established and maintained, allowing a single participant to control a collaborative session involving participants they have no previous relationship with.

Identity and Representation of Collaborators

Within any collaboration environment, membership is necessary, enabling individual participants to know who is talking and who is receiving or providing information within an often-faceless collaboration. Collaboration sessions involving participants that have never met introduce issues of trust and acceptance. Visual representation and contextual background information help participants understand each person's position in the session and their credentials on an as-needed basis. Knowing who is speaking and their qualifications greatly improves interactions among participants, which justifies protocol enforcement and establishment of information policies.

Information Policy and Protocol Enforcement

Between sessions and conversations, knowledge and resources need to be transferred to ensure current information is being used. A field rescue collaboration session is at a great disadvantage if it cannot access information generated in a resource management session that is responsible for directing field agents. In a hierarchical, multi-session environment, information dissemination and encapsulation are of key importance. During a single collaboration session, an unknown number of applications are used, requiring the information policy to be independent of any application. The information policy can be implemented in a central location, acting as the interface between the participants and the collaboration session. By removing the policy implementation from the client, control can be centralized.

Persistence of Collaboration Data

Information generated during one session needs to be available to other sessions, during and after. Persistent storage of all information generated during a collaboration session maintains consistency among participants and can be used later for detailed inspection of collaboration sessions. Training exercises and facility updates directly benefit from the examination of historical information, placing an additional requirement for persistency of collaboration information.

Consistent Representation Between Collaborators

Utilizing a common repository for all transactions, collaborators can be assured that their session is up to date with others. Each transaction affects a single source, enabling latecomers to build the session to the current state or retrieve the current state of the session in a single request. During loss of service, participants can store transactions locally, executing them once a connection to the session is re-established.

Session Replay and Analysis

Since all transactions are executed on a repository of information, the transactions themselves can be stored. Transaction logs can be replayed at a later date for study of a collaboration session or to search for a particular piece of information. Replay features are very important for training sessions and can be invaluable for studying the performance of participants in a particular collaboration session. High-level collaboration sessions can also study lower sessions in real time, monitoring progress and providing feedback.

Synchronous/Asynchronous communication

There are various kinds of communication technologies can be integrated into the virtual collaboration environment. They are categorized as Asynchronous and Synchronous ways:

- Asynchronous
  - E-mail
  - Group calendars and schedules
  - Bulletin boards and websites
  - Non-real-time database sharing and conferencing
  - Work-flow applications
- Synchronous
  - Desktop and real-time data and application conferencing
  - Real time application interaction
  - Whiteboard
  - Instant message and online chatting
  - Electronic meeting systems
  - Video conferencing
  - Audio conferencing

Multiple-Device Supported Collaboration

In the collaborative learning process, the distributed team members may access the virtual collaboration space from different computing environment. Technology, both hardware and software, develop so fast that collaboration systems should be improved in both functionality and applicable scopes by making full use of some cutting edge technologies. The widespread proliferation of wireless networks and increasing use of small, portable computers has stimulated mobile or nomadic computing. Mobile computing and wireless network has increase the flexibility and accessibility of collaboration space, and enable the learning team members to interact with each other anytime anywhere. Information sharing, online meeting and real-time application interaction can be realized from the traditional desktop, laptop, wireless-capable PDA (**P**ersonal **D**igital **A**ssistants) as well as next generation data phones (smart-phones) or pagers through both wired and wireless network.

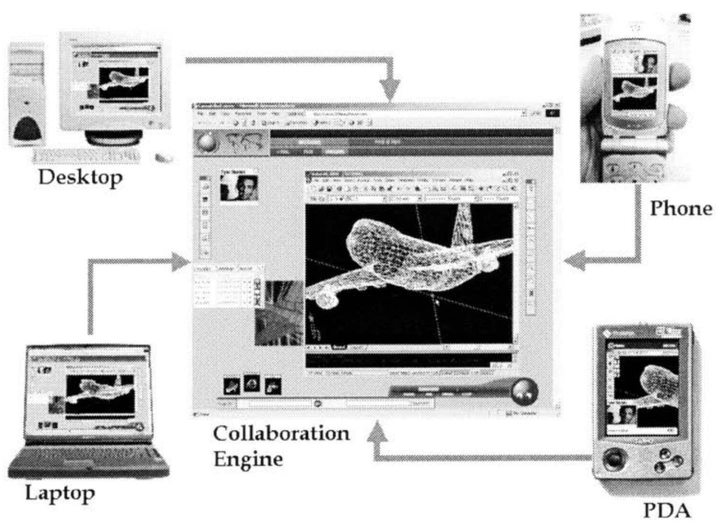


Figure 3-11: Multiple-Device Supported Virtual Collaboration

Application Sharing and Interaction

Except for the traditional collaboration means, such as email, instant message, bulletin board, whiteboard, audio/video channel, agenda control, the collaboration system also provides a application server which will enable the distributed team participants to share and interact with the same application like CAD (shown in Figure 3-12) and project management software to solve complicated problems in real time. This allows the collaborative learning team to utilize the distributed expertise and skills of different members to discuss, demonstrate and analyze the problems together in the virtual environment to reach effective solutions.

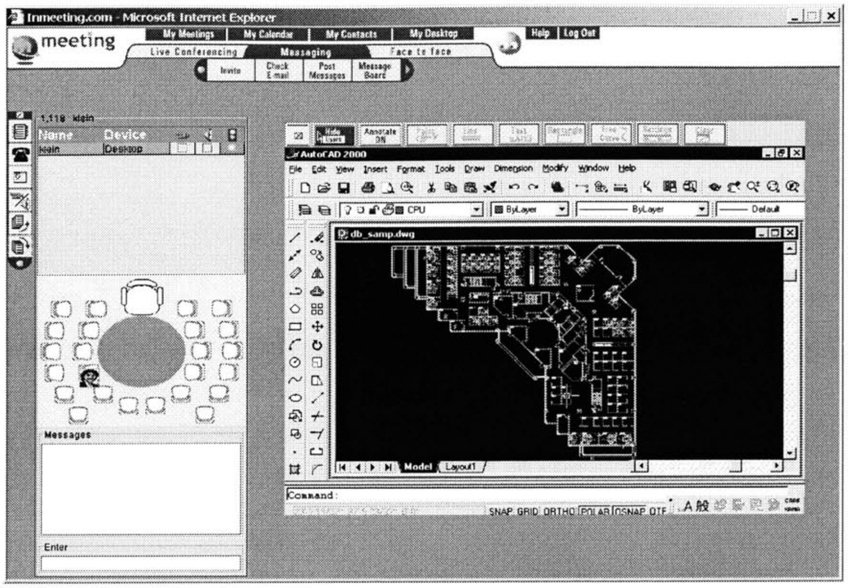


Figure 3-12: Real-time Application Sharing and Interaction (CAD)

The system design of the Virtual Collaboration Space is not the focus of this thesis, more detailed information can get from research papers of DaVinci Initiative at MIT (Kuang, 2001).

Chapter 4 Collaborative Learning Assessment Model

4.1 Collaborative Learning and Assessment Iterative Cycle

The previous chapter dealt with the fundamental constructs of the distributed team collaborative learning and interaction environment and also described the barriers to team collaborative learning effectiveness and health. However, it also should be understood that learning teams do not function in a vacuum, but function inside a distributed team collaborative learning framework, which captures the collaborative learning and assessment iterative cycle in a holistic sense. The learning behavior of individual or team is not a simple linear or waterfall process, but an iterative cycle that will be influenced by outside conditions and environment. Especially for collaborative learning, the improvement for understanding of knowledge is accompanied by adjustment of learning process, methods and team dynamics to overcome various barriers.

The Collaborative Learning and Assessment Iterative Cycle captures the iterative nature of an effective collaborative learning and interaction process in the collaborative environment that includes the whole range of learning activities: from carrying out learning interactions and collaborations in the distributed team interaction space and team virtual collaboration space; to observing the barriers to effective learning and interaction by evaluating the effectiveness variables in the collaborative learning environment; to mapping individual and team performance to Collaborative Learning Team Effectiveness Continuum (discussed later in this chapeter) and comparing them with the desired effectiveness state; to identifying areas of improvement and making adjustments to remove these barriers in order to increase learning effectiveness and maintain team health.

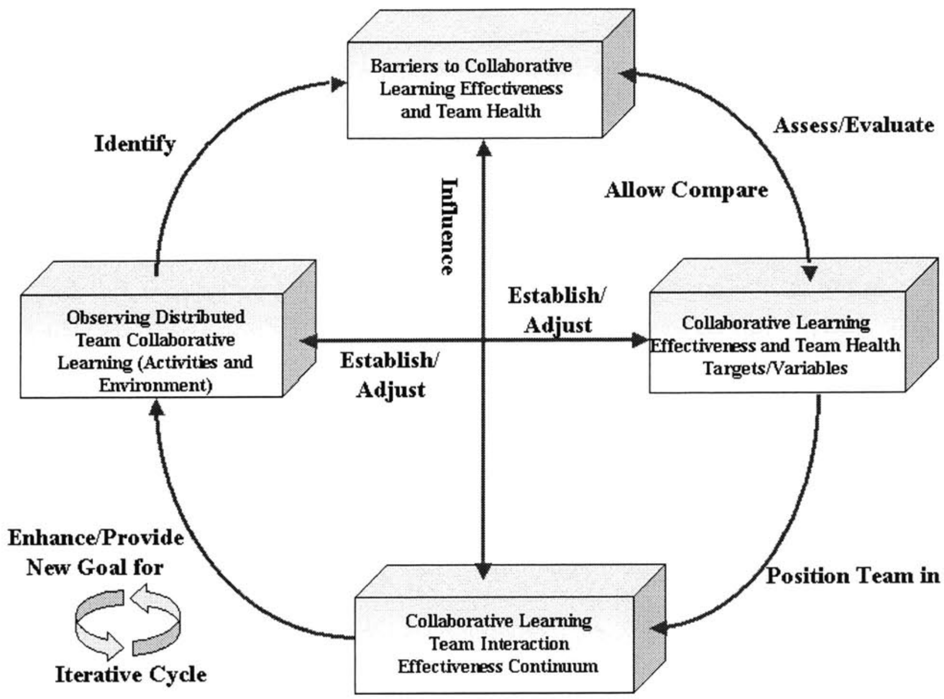


Figure 4-1: Collaborative Learning and Assessment Iterative Cycle

The collaborative learning and assessment iterative process steps as shown in Figure 4-1 are:

- Identify barriers to team collaborative learning effectiveness and team health through observation of the learning interactions and collaborations carried out in the collaborative learning environment, analyze deviations from desired state as indicated by effectiveness targets
- Evaluate collaborative learning individual and team effectiveness and performance by measuring the collaborative learning effectiveness and health variables through multi-dimensional assessments carried out in virtual collaborative learning environment
- Position the learning team in the Collaborative Learning Team Interaction Effectiveness Continuum with assessment results
- Assess the individual and team performance, learning effectiveness and team health targets after positioning the team on the team interaction space effectiveness continuum and compare them with the desired effectiveness state to find the gap

- Provide revised goals for further collaborative learning and interaction, and adjust the learning environment (course setup, organization, team dynamics, teaching/learning processes or infrastructure) for enhancement with knowledge of current team effectiveness status and feedbacks
- During the iteration, the learning effectiveness and health assessment variables can be adjusted or new variables/targets will be established after comparing them with current effectiveness barriers. They can also be established and adjusted by the dynamics of leaning environment
- The targets of the learning effectiveness and team health will also influence the collaborative learning environment setup and learning process. And collaborative learning assessment space will be establish or changed due to different assessment variables and purposes
- Iterate the cycle over time, as the learning interactions are dynamic and as the framework shows the cycle is repeated over time

4.2 Collaborative Learning Team Interaction Effectiveness Continuum

Throughout the collaborative learning process, how to improve overall team performance, team interaction effectiveness and team health is a critical problem for a successful learning in the distributed environment. Most globally dispersed learning teams appeared to improve in a spiral fashion, with frequent iterations between each state. The Team Interaction Effectiveness Continuum is a spiral curve mirroring the real life growth of a virtual learning team from its inception when it is just a collection of combative people with conflicting ideas to an optimized group with efficient processes for effective use of the distributed team interaction space. What needs to be stressed however is that a team newly formed, can join the spiral curve at any level of proficiency on the team interaction space effectiveness continuum. Even small deviations in team composition or the environment can move the team up or down the team interaction effectiveness continuum. The effectiveness continuum relates the team to the effectiveness barriers, which hamper the team from a more effective interaction, to the effectiveness targets that they would expect to achieve for learning as they improve their interaction process over time. The effectiveness targets are the indicators of the team interaction performance and are measures/deliverables that the interaction process would have at specific and defined checkpoints.

The metrics/checkpoints that serve as indicators of what is wrong or what are the barriers to their collaborative learning interaction, which they need to consider and eliminate. The interaction space effectiveness continuum is shown in Figure 4-2 below (Sen. 2001).

The continuum are designed to provide guidance on how to continuously improve the ability of leaning teams to attract, develop, motivate, organize, and retain the teams needed to steadily improve team learning capability and health. In summary, the goals of team interaction effectiveness continuum are to help learning team to:

- characterize the maturity of their team practices
- guide a program of continuous team development and improvement
- integrate team development with process improvement
- identify potential strengths and weakness in team practices against a standard
- build consensus around fundamental team problems
- set priorities for improvement needs
- provide guidelines for teams to improve team performance

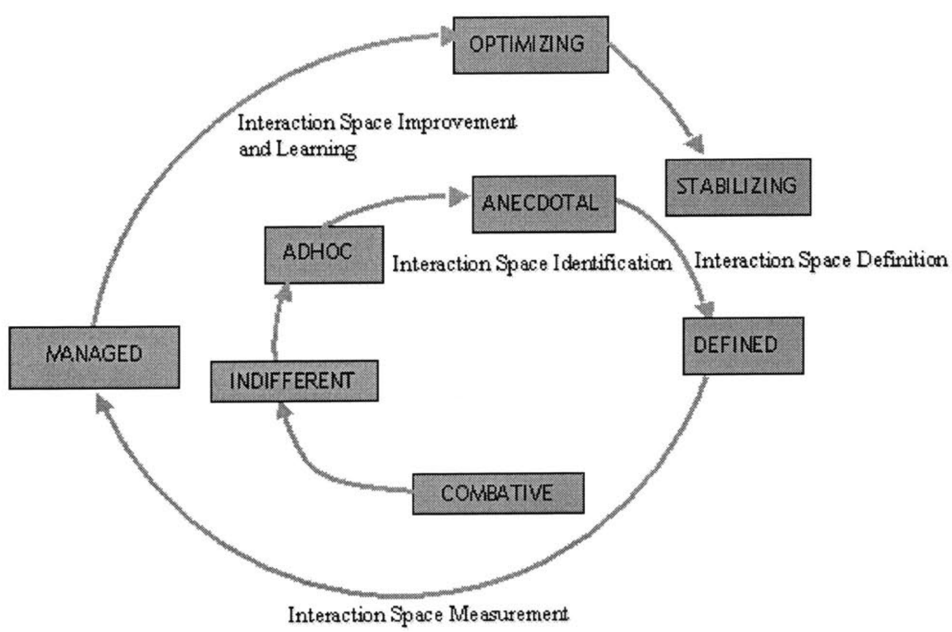


Figure 4-2: Collaborative Learning Team Interaction Effectiveness Continuum (Sanjeev, 2001)

Eight different levels and their corresponding key areas are defined. In addition, some of the different levels are further characterized based on:

- An Organization theme that defines how the organization can establish and maintain a framework that supports its teams
- A Process theme that defines the nature of the work processes and team needs
- A Tools theme that describes the tools and technologies used by the team

The different stages in the team effectiveness continuum are [Pena-Mora, 1999; Pena-Mora 2000]

- Combative
  - ➢ Lack of team alignment
  - ➢ Interpersonal conflict and disregard for others
  - ➢ Technology used as a means to stress the inequalities as a measure of importance
- Indifferent
  - ➢ Total lack of disregard for team issues.
  - ➢ Lack of interest in team
  - ➢ Technology misused and stresses the disenchantment of members in the interaction process
- Adhoc
  - ➢ No available standards
  - ➢ Interaction processes undefined
  - ➢ Effective by chance and chances of successful replication remote
- Anecdotal
  - ➢ Some standards, mostly borrowed
  - ➢ Communication primarily push
- Defined
  - ➢ Team has its own set of protocols whose applicability and need are not well understood
  - ➢ Team has identified some barriers and their relation to team effectiveness
- Managed
  - ➢ Defined and documented interaction processes
  - ➢ Communication transitioning from push to pull
  - ➢ Infrastructure for building and utilizing corporate memory in place
- Optimized
  - ➢ Improved global learning

- Ability to work anyplace and anytime
- Team metrics optimized regularly

- Stabilization and Improving
  - Steady state, which can be impacted by several disturbances thus bringing the team interaction space effectiveness down to any of the above stages

4.3 Importance of Collaborative Learning Assessment

In the distributed team collaborative learning iterative cycle, one of the important activities includes assessment of collaborative learning effectiveness and team health, and evaluation of individual or team performance during the whole learning and working process. The positioning of the learning team on the collaborative learning team interaction effectiveness continuum is indicative of the health of the team and learning effectiveness. This is achieved through various collaborative learning assessments described herein. The results of measured effectiveness variables will map to a specific evaluation of the team by its positioning on the team interaction effectiveness continuum. This evaluation and positioning provides solutions to the collaborative learning team regarding what it should be doing to conduct student Cognitive Learning practices, to guide the individual's learning process and self-development, and to improve the team interaction effectiveness and healthy cooperation. The collaborative learning assessment model provides such values directly to the individual students, learning teams and instructors as:

- Leading and guiding development – guiding the individual learning at a level-appropriate pace in different phases and leading class/team development in a healthy and effective way

- Establishing and maintaining team focus – defining distributed team structure and controls, controlling the attention of the distributed team; guiding the participants towards the final learning objectives and maintaining a common line of reasoning in collaborative learning process

- Measuring and positioning – measuring participants and team collaborative learning effectiveness assessment variables and metrics; positioning team in the interaction effectiveness continuum to identify the level of team collaboration in order to provide guidelines to increase the overall effectiveness of team learning and collaboration

- Requesting and providing feedback – getting feedback about participants' understanding of knowledge, evaluation and suggestion of learning process, instructors and TA capability, course setup and collaboration technology; informing the class and individuals of the observations; providing feedback about the effect of their behaviors in the collaborative learning process

- Evaluating and encouraging – conducting various kinds of assessments to evaluate participants' understanding of knowledge, individual performance based on perceived contribution to the teamwork and team performance; encouraging participation in the project-base teamwork and stimulate healthy cooperation between participants.
- Recording and reflecting – recording individual and team thinking and working processes; helping student move from doing to reflecting to get higher-order knowledge about how to get knowledge and understanding; conducting cognitive learning practices to enhance the educational level
- Tracing and monitoring – providing instructors with mechanism to trace the students' answers and testing behavior of using different simulation tools which guide the learning in more effective and intelligent way; monitoring the individual and team learning progress at any time or over time in different learning phases
- Analyzing and adjusting – quantitative and qualitative data collected through assessment will be synthesized and analyzed to discover the individual or team behavior; adjusting the current team dynamics between various participants of the team, and supporting group decision-making
- Identifying and improving - identifying barriers of learning effectiveness in terms of course setup, teaching schedule and information technologies used for learning; shaping a better solution to improve learning effectiveness and collaboration health

When the collaborative learning are being carried out and the Virtual Collaborative Learning Environment are being designed, how to evaluate and improve the effectiveness of learning, interaction and collaboration for the individual and the whole team, will be the main challenge and focus throughout the process.

4.4 Collaborative Learning Team Performance

In the collaborative learning context, except for the individual leaning, most of the learning processes involve team interaction and teamwork for the common learning goals or projects; thus, team performance will be one of the criteria to evaluate the effectiveness of collaborative learning. There are a number of theories that discuss the developmental stages of team performance. One of the most widely used team performance theories, advanced by (Tuckman 1965) is comprised of five stages: forming, storming, norming, performing, and adjourning. Initially, during the socialization phase of team formation, members are just beginning to learn about one another. The group then moves into the storming stage, where members become more proactive and take on specific tasks and roles. A real sense of cohesion in the group develops in the norming stage. During the performing stage there is an increase in task performance as deadlines approach. Finally, like most teams, the task ends and the team are adjourned. Lacoursiere (1980) developed a five-stage model that portrays the group as being a living organism that responds to stresses in the environment and either matures as a result of the stress or dies. Lacoursiere's (1980) model states that teams progress through orientation, dissatisfaction, resolution, production, and termination stages and the model shares many similarities with Tuckman & Jensen's (1977) model.

Both of these theories were initially applied and tested in traditional team settings. Sarker et al. (1999) designed a team development model for globally dispersed teams. They propose that global learning teams progress through four stages of development: initiation, exploration, integration, and closure. The first stage, initiation, is similar to the first stage of other models and describes the period during which the group forms. During the exploration stage, team interaction is of paramount importance. Interactions can be either unidirectional or bidirectional. Teams that interact uni-directionally tend to operate in a sporadic manner and are unable to communicate content between team members. During the integration stage, members involved in bi-directional communication relationships respect each member's abilities and have open and meaningful interactions. Finally, the group reaches the closure stage. Once again, depending upon the performance level, group members may face a number of different emotions.

4.5 Collaborative Learning Team Effectiveness

Although *effectiveness* has been defined in several ways, there has been general agreement on its fundamental characteristics. For example, McGrath referred to effectiveness as the *functions* that a team performs, labeling them the production function, the member-support function, and the group well-being function. (Hackman, 1987) used a similar framework, describing an effective team as containing:

productivity meeting or exceeding customer expectations,

a) capability for working together in the future, and

b) satisfaction of group members.

Following Hackman's (1987) definition, this thesis suggests that effective teams can be defined using three criteria.

- First, the learning outcomes of the team effort must meet or exceed the standards for quantity and quality as set by the organization.
- Second, the team experience must satisfy the personal needs of team members in the collaborative learning.
- And third, the social processes that allow the team to function must maintain or enhance the capability of team members to learn and work together.

Sundstrom et al. (1990) adopt a definition of team effectiveness that incorporates productivity, satisfaction, and sustainability.

Primarily, teams are organized to accomplish the learning objectives of the class. Therefore, any evaluation of the collaborative learning effectiveness of a team must include the degree to which the team accomplishes its goal of learning and project work. The productivity of a team is defined as the degree to which the team "*... meets or exceeds the expectations of the performance standards of the people who receive and/or review the output...*"(Hackman, 1987). Teams also serve an individual function in the lives of their members (McGrath, 1991). In order for a learning team to be effective, it is necessary that the process of learning and working together satisfies the social and task needs of the group members, resulting in their being satisfied with their experience in the team. Team member satisfaction also is a likely prerequisite for team sustainability. Team sustainability represents the team's capacity to successfully study or work together in the future. For example, a team may be productive and deliver a high quality project results but the process of accomplishing the task and learning may destroy the group's ability to continue studying and working together. Such a team would obviously be considered less effective than a team that had interacted in such a way as to allow for future productivity. The above-mentioned dimensions of team effectiveness in collaborative learning represent the multidimensional nature of effectiveness found in the literature that has been correlated in prior studies. Definitions of effectiveness should include both team-level and individual-level indices of effectiveness variables.

4.6 Learning Effectiveness and Team Health Assessment Variables

To evaluate collaborative learning and interaction effectiveness as well as team health, diverse effectiveness and health assessment model elements and variables have been identified and summarized as below (Manasseh, 1999), (Prodonoff, 1999), (Gladstein 1984), (Hackman 1987):

- Individual Perceptions – individuals form the team. Thus, the value of individual perceptions about the learning and team directly affect the effectiveness of collaborative learning and interaction processes carried out by these people. The issues are
  - Understanding of learning objectives and team common goals
  - Improvement of acquired knowledge and skills
  - Individual outcomes and deliverables
  - Learning process and behavior
  - Contribution to teamwork and collaborative learning
  - Participation and agility in decision-making process
  - Support for team members
  - Trust and satisfaction in distributed learning team members
  - Belief in organizational culture
- Team Outcomes – the team is usually brought together for a specific project to achieve a particular learning goal. The evaluation of team performance and the criteria on which such judgments are based form this section. The issues here are
  - Focus of team attention on learning objectives
  - Team performance in terms of deliverables
  - Relative knowledge and skills improvement through distributed team participation
  - Collaborative learning team progress and behavior
  - Team satisfaction
- Team Structure and Processes – it encapsulates most team processes and the team structure related issues. Broadly, these issues are
  - Cumulative and matching technical and social competencies of team members
  - Norms for team member learning behavior
  - Transitioning of distributed team members on or off the team
  - Mechanisms for knowledge and expertise sharing
  - Effect of diversity of distributed member on team bonding and interaction

- ➢ Information flow mechanisms
- ➢ Teaching and learning process satisfaction

The variables can be subdivided into

i. Team Composition – this variable relates to the team composition which is affected by

- ➢ Adequate Skills – the skill set of the team members
- ➢ Heterogeneity – the degree of heterogeneity of the team members
- ➢ Language Barriers – this relates to the difficulties faced by team members as the language of interaction is often not the language in which team members are comfortable in
- ➢ Cultural Barriers – the cultural differences amongst team members

ii. Group Structure – this relates to the way the work gets done in the team. This variable encompasses a number of sub-variables like

- ➢ Role and Goal Clarity – the degree of clarity amongst team members about assigned learning tasks
- ➢ Work Norms – the process in which tasks are done
- ➢ Task Control – the allotment of tasks and the relative importance
- ➢ Size – the size of the team
- ➢ Leadership – the kind of leadership that the team is using, the degree of empowerment of the team members

- Collaborative Learning Interactions – the team interacts predominantly through virtual collaboration space and through asynchronous means in team interaction space. The important issues in team interaction processes are

  - ➢ Knowledge about the distributed members
  - ➢ Effectiveness of face-to-face and virtual team meetings
  - ➢ Capability of distributed team members in running virtual meetings
  - ➢ Adequacy of agenda in meetings
  - ➢ Problems in learning interaction
  - ➢ Process of experiences (lessons) sharing and assimilation
  - ➢ Balanced distribution of tasks amongst members
  - ➢ Motivation – the team member involvement in the team interaction process
  - ➢ Trust – the degree of trust that team members have for each other
  - ➢ Open communication channels – the degree of openness of communication channels
  - ➢ Supportiveness – the degree of support that team members receive in their daily functioning from the team
  - ➢ Conflict management – the manner in which conflicts are managed in and outside the team

- Collective decision-making ability – the ability of the team members to take decisions as a group
- Boundary management – the way the team interfaces with the larger environment both within the parent organization and the external world.

- Collaborative Learning Task
  - Task complexity – the degree of complexity of the task to be done
  - Impact of environmental factors – the way the environment affects the nature of the task
  - Task interdependencies – the dependencies of the task on external factors
  - Task uncertainty – the degree of uncertainty in the task in terms of whether it can be done or not
  - Task sensitivity
  - Task reliability – the requisite reliability of the task required
- Collaborative Learning Team Support – the learning team needs a lot of support both in terms of individuals, infrastructure as well as high-level support for the team.
  - Contribution of individual knowledge, skills and effort to teamwork
  - Leadership in teamwork and learning
  - Performance evaluation and reward processes
  - Local perception about distributed team processes
  - Capability and willingness to help distributed members
  - Sharing lessons from small team level to a broader organizational level
  - Teamwork satisfaction
- Communication Technologies – The distributed team will be using a suite of communication technologies to facilitate their interaction with dispersed team members. There are a number of issues pertaining to the use of these communication technologies. Some of the broad issues are
  - Needs for the team collaboration
  - Relevancy of communication technologies in fulfilling team collaboration needs
  - Capability of technologies in terms of usability, functionality and reliability (Synchronous and Asynchronous Communication facilities)
  - Facilitation of team interaction processes by adequate technologies
  - Adequacy of the technologies used in providing reliable and correct information
  - Accessibility of technical facilities to team members
  - Presence and adequacy of support and training for team in using technologies
  - Technology satisfaction

4.7 Multi-Dimensional Assessment Model

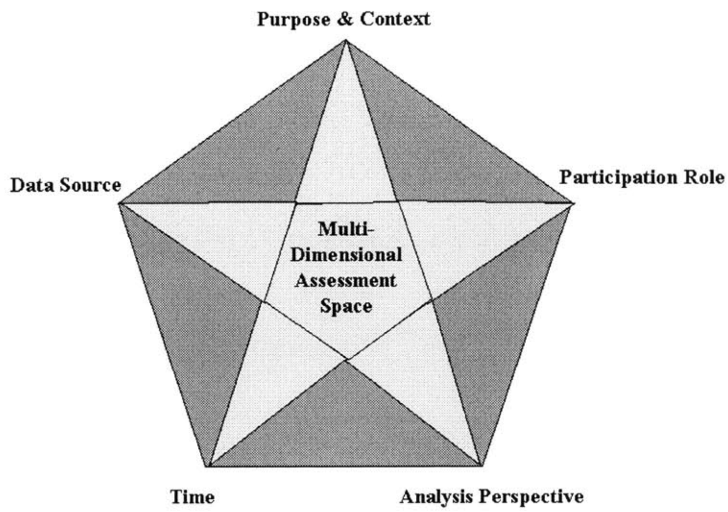


Figure 4-3: Multi-Dimensional Assessment Model

The collaborative learning effectiveness and health variables identified in the previous sections are evaluated through various kinds of learning assessments carried out in Collaborative Learning Assessment Space. Through the research, when we design the collaborative learning assessment space, a multi-dimensional assessment model has been defined to implement a comprehensive assessment scope to be managed, controlled and analyzed from different perspectives according to the requirements of each collaborative learning assessment. The multi-dimensional assessment scope can be built up from five dimensions: assessment purpose and context dimension, assessment data source dimension, assessment time dimension, assessment participation role dimension and assessment analysis role dimension. Under each dimension, there are several assessment perspectives. Each assessment context can be created and viewed from different single perspective or combined perspectives of different dimensions. The multi-dimensional model is analyzed as follows:

4.7.1 Assessment Purpose and Context Dimension

An assessment can be defined and created from the purpose point of view. To evaluate different effectiveness variables and identify barriers to different aspects of collaborative learning and interaction, the survey and assessment should have specific targets. According to the key components of the collaborative learning environment and classification of learning effectiveness and team health assessment variables diagnosed in the previous sections, four standard assessment contexts are defined as follows to collect data from the students with clear focus on different objectives of learning assessment. Each assessment outcomes are valuable for analysis and improvement of specific aspect of effectiveness of collaborative leaning.

Self Assessment – Participants need to evaluate their own understanding of goals, their improvements of knowledge and skills, self performance and behavior in the collaborative learning and interaction, their contribution to the final learning outcomes and teamwork and their participation and agility in decision-making process. In Self Assessment the instructor also guide the student's individual learning at a level-appropriate pace by different learning phases, and give instructions or hints about deep thinking rather than surface memory. Through Self Assessment, one's own thinking and learning processes can be recorded, which reflect the individual learning behavior and progress, such as using Interactive Simulation Assessment to track the student interaction process and answer behavior when students play with simulation tools for self-learning. From the feedback of the assessment, students can have knowledge about their own understanding process and learning progress, and can avoid repeating mistakes by identify the common obstacles for understanding. Instructors can use the data to monitor and analyze students' learning behavior and get individual results and cumulative team results for performance evaluation. In summary Self Assessment is conducted from individual perspective of the collaborative learning and help the students to build up intellectually self-watchful, self-guiding and self-assessing skills.

Peer Assessment – Participants need to evaluate their peers in the same learning (sub) team or project (sub) team based on their perceived performance and contribution to each other and the team during the teamwork, interactions and collaborations of learning. Each team member will assess and give feedback about other peer' contribution of individual knowledge, skills and effort to teamwork, other's sharing of lessons and experiences, other's capability and willingness to help distributed members, other's leadership in teamwork and learning, other's participation in team problem-solving and decision-making and other's affect to team morale and trust building. Students will also provide friendly suggestion and comments for their peers. The results of the peer assessment will be used as one of the metrics for evaluation and grading for individual and team, based on the performance and competency. From the feedback of Peer Assessment, instructors can also monitor the relationship between team members and team health, identify and solve conflicts and adjust team dynamics (team structure, responsibilities, workload, member roles, etc.) to improve the effectiveness of team collaborative learning and maintain team development health. In the project based course, a participant maybe assigned to different sub teams during different stages of the project, then peer assessment can be used to analyze each individual behavior in different sub teams as well as different team feedbacks for the same individual at different time. In summary Peer Assessment is conducted from peer to peer perspective of the collaborative learning and focus on the learning team support. It encourages students' participation in the project-base teamwork, their contribution to the learning objectives and team building, and stimulates healthy relationship and cooperation between participants.

Team Assessment – Participants need to evaluate their team performance and effectiveness after learning and working in such a team collaborative learning environment. Each team member will evaluate and give feedback about the team composition and dynamics that influence the learning and interaction effectiveness, such as team composition (adequate skills, heterogeneity, language barriers, cultural barriers), team structure (role and goal clarity, work norms, task control, team size, leadership), team process (mechanisms for knowledge and expertise sharing, information flow mechanisms, transition of distributed team members), team collaborative learning interactions (motivation, trust, morale, open communication channels, supportiveness, conflict management, collective decision-making ability, boundary management, balance of workload, process of experiences sharing and assimilation), collaborative learning task (task complexity, task interdependencies, task uncertainty, task sensitivity, task reliability, impact of environmental factors), and team outcomes assessment. The results of Team Assessment can help instructors to identify the barriers to current team learning and interaction effectiveness, and position the team in the Team Interaction Effectiveness Continuum. Instructors can get more sense about how to construct a successful team and how to adjust current team dynamics to overcome those barriers. In summary Team Assessment is conducted from individual to team perspective of the collaborative learning and focus on the collaborative learning team structure, process and behavior.

Leader Assessment – This is the most common assessment carried out in school nowadays after finish of each course. All the course participants need to evaluate the instructors, the teaching assistants and overall course settings. Participants will give assess the instructor's teaching behavior and methods (organization of lecture, management of class discussion, presentation and visual aids efficiency and legibility, clarity of explanation, process of assignments and exams, enthusiastic of subjects and teaching, respect to students, consideration of students' background and experience, punctuality of attendance, management of learning process, control of learning atmosphere), teaching assistant proficiency (understanding of the subject, organization of teaching assistance, knowledge of content, availability of help, patience of assistance), subject content and settings (level of hardness, sufficiency of theoretical content, efficiency of practical and management application, supplementary of assistant reading and materials, workload of assignments and homework, effectiveness of assignments and exams for understanding, help of computer supported learning experience), and constructive comments and suggestions about the course and learning process. These feedbacks can be used to evaluate the instructors and teaching assistants' performance and help instructors to adjust and optimize the current teaching process to achieve the educational goals throughout the course. In summary Instructor Assessment is conducted from student to instructor perspective of the collaborative learning and focus on the collaborative learning subject content, teaching methods and instructor performance to improve the teaching effectiveness.

Facilitator Assessment – To fulfill the task of collaborative learning for distributed team, different advance communication and collaboration technologies have been implemented and integrated to assist the knowledge management, collaboration, interaction, as well as the learning assessment. However, the participants need to analyze the effectiveness of the facilitators in the collaborative learning environment (the team interaction space, virtual collaboration space and learning assessment space) and infrastructures. Through Facilitator Assessment, they evaluate the spatial setup, digital setup, capability of technologies (usability, functionality availability, accessibility and reliability), interaction protocols and policy used, facilitation of team interaction processes by adequate technologies and relevancy of communication technologies in fulfilling team collaboration needs. This helps the instructors to find out the barriers due to infrastructure and technology, and make better solutions to utilize and coordinate the technology resources to serve the physical and virtual collaborative learning environment most. In summary Facilitator Assessment is conducted from participant to facilitator perspective of the collaborative learning and focus on optimizing the physical setup and virtual collaborative learning technologies, to realize a most effective collaborative learning environment.

4.7.2 Assessment Data Source Dimension

When design the learning assessment, it has to be determined which kinds of data to be collected and what appropriate mix of data collection techniques to be used, including both quantitative and qualitative approaches. In a broad sense, quantitative data can be defined as any data that can be represented numerically and be presented or analyzed by machine easily, whereas qualitative data are more frequently expressed through narrative description. Quantitative data also are useful in measuring the reactions or skills of large groups of people and can produce a rich data source that is easy for analysis and can be highly informative, whereas qualitative data provide in-depth information a smaller number of cases (Patton, 1990). However, these distinctions are not absolute two discrete categories, in some instances qualitative data can be transformed into quantitative data using judgmental coding (for example grouping statements or themes into larger broad categories and obtaining frequencies). Conversely, well-designed quantitative studies will allow for qualitative inputs. Both types data source can provide measurements of the learning effectiveness variables for decision-making; both should be considered in planning and designing an assessment. Frequently, an assessment uses a mix of data sources for different purpose depending on the evaluation question, target effectiveness variables and issues, data collection and analysis instrument capability. Thus, under Assessment Data Source Dimension, there are two perspectives of data sources considered for assessment design that have been defined in the collaborative learning assessment space for this research.

Quantitative Assessment (Integrated Assessment): In different phases of the learning and working process, the participants take the integrated survey of quantitative questions about the knowledge, learning, collaboration, organizational process and infrastructure or recording for learning process in different assessment contexts described under Assessment Purpose and Context Dimension. In integrated assessment, most target questions and effectiveness variables can be formulated in quantitative way or need to be analyzed quantitatively. They can be presented in various kinds of question formats and styles (Single Choice Question, Multiple Choices Question, Rating Question, AnswerBar Question, AnswerBox Question, List Question) under predefined categories. These collected quantitative data can be conveniently analyzed statistically and compared from different perspectives in the collaborative learning assessment space and reported in learning assessment matrix. Meanwhile, abundant statistic results and dynamic graphics/charts can be generated on fly.

Qualitative Assessment (Learning Journal): Learning Journal or Design Notebook for the course is required for the collaborative learning team participants. It is for participants to reflect on their collaborative interactions with each other, their understanding knowledge, comments and suggestions for the course and team. As the course, team and collaborative interaction are still evolving on all levels, cultural as well as professional insights of the participants should prove valuable for the improvement of the course and team/class. Rich and in-depth information can be collected from the qualitative assessment, which helps the instructors have better understanding of the individual thinking and solve conflicts or problems influencing learning effectiveness.

4.7.3 Assessment Time Dimension

For all types of assessments, the evaluator must decide the frequency of data collection and the method to be used if multiple observations are needed. For many purposes of assessment, it will be sufficient to collect data at one point in time; for others one time data collection may not be adequate. Collective assessment may utilize either multiple or one-time data collections depending on the length of the course or project, any problems that may be uncovered along the way and the effectiveness variables that need to be measured, such as: how different team evaluate the same person for a specific project or how different teams evaluate the same person for different projects over time. For summative evaluations, a one-time data collection may be adequate to answer some evaluation questions, such as: how many different countries and cultures the students come from or what are the most popular programming language among the collaborative learning students. Usually, such data can be obtained from the records at once. But impact measures are almost always measures of change, such as effectiveness improvement along the learning process. Have students understood the project goal more clearly? Have teachers adopted different teaching styles? Have team have better performance and cooperation after several assignments? In each of these cases, at a minimum two observations are needed: baseline (at course initiation) and at a later point, when the course or project ahs been operational long enough for possible change to occur.

Quantitative studies using data collected from the same population at different points in time are called **longitudinal studies** (NSF Evaluation Handbook). They often present a dilemma for the evaluator. Conventional wisdom suggests that the correct way to measure change is the "panel method," by which data are obtained from the same individuals (students, instructors, parents, etc.) at different points in time. While longitudinal designs which require interviewing the same students or observing the same group at several points on time are best, they are often difficult and expensive to carry out for distributed team because the members are flexible and may move or change group over time. Thus, as assessments that involve repeated data collection usually require that the data be collected using identical survey instruments at all times, the electric collaborative learning assessment space is the best and most flexible solution. In this collaborative learning assessment space, Single Assessment and Series Assessment perspectives are defined under Assessment Time Dimension.

Single Assessment: The assessment used to monitor and analyze the one-time behavior of individuals and team, collect summative information of a team about the team structure and processes, or get collective data of different individuals and teams for the same target variables at a specific time. Statistical analysis of responses at one single point in time can be generated.

Series Assessment: All assessments can be carried out along the time axis to form a series of assessment within a same assessment context. As the individual progresses and team develops gradually in the learning process, information about the change of collaborative learning participants' attitude, the process of one's understanding of knowledge, the progress of the team interaction, or the improvement of team collaborative learning effectiveness though monitoring effectiveness and health variables, can be colleted from Series Assessment over time. Various statistical collective or progressive results with visual graphs/charts can be generated dynamically in longitudinal reports, to help the instructor analyze individual/team behavior for some purpose over time.

4.7.4 Assessment Participation Role Dimension

In the Assessment Space, all the assessments can be created for evaluation of different aspects of participant or organizer, such as Self Assessment and Peer Assessment for participant, and Leader Assessment for organizer. In the other hand, all assessments designed in the assessment space can be taken and managed from either participant or organizer perspective under Assessment Participation Role Dimension

Participant: The participant of the course and collaborative learning can be student, learning team member or project participant in the learning environment.

Organizer: The organizer of the course and collaborative learning can be teacher, instructor or team leader who manages the course or lead the team, creates the learning assessment, guide the learning assessment, and maybe analyze the results of the observations in the collaborative learning environment.

4.7.5 Assessment Analysis Perspective Dimension

After collecting all the required intentional data of different learning assessments at single point of time or over time, the focus changes to how to analyze and use the data to generate useful statistic information and reports for the instructor to evaluate current collaborative learning effectiveness and team health, find out barriers to individual and team development, and make out effective solution to overcome these barriers to reach optimal objectives. Each analysis can be done from individual perspective or team perspective under Assessment Analysis Perspective Dimension in the assessment space.

Individual Perspective: Analyze the data of individual (data collected from each individual) or for each individual (maybe the collective result for evaluation of each team member's performance in peer evaluation). The results are used to track each student's understanding of knowledge, to evaluate individual performance, to get individual feedback and monitor individual learning behavior.

Team Perspective: Synthesize all the data collected from each individual of the collaborative learning team and generate collective or summative reports of cumulative statistic results. These results are use to get knowledge of the distribution of members' feedback within the team, team overall evaluation for target effectiveness variables and group behavior of learning team through the process. More useful results are from longitudinal studies of Series Assessment.

4.8 Collaborative Learning Assessment Space

Based on the multi-dimensional assessment model, through this research a collaborative learning assessment space has been created as a powerful instrument to define an assessment and to analyze the results for specific purpose with multiple dimensions. This is a very useful abstraction for design of the real learning assessment space system in Virtual Collaborative Learning Environment and visual guidance for creation and analysis of assessments. The assessment space can be constructed with different combination of dimensions analyzed in the previous section, according to the capability of the system and assessment objectives. For simplification each assessment space is visualized as a 3D space with three basic dimensions; each initial assessment is shown as a point in the space and can be developed along each dimension to form various derived assessments for different design and analysis purposes. In this thesis, participant dimension, time dimension and assessment objective dimension (Question Set in real assessment system) are explicitly chosen to make up the assessment space to create example assessment, which has been realized in Collaborative Learning Assessment Support System (CLASS) (designed in Chapter 5). As implicitly each assessment positioned and defined in the space can be used for all assessment contexts, another assessment dimension of purpose and context is involved but not shown in the assessment space. For most of the circumstances in this research, an assessment or a series of assessments implemented for individuals in a learning team are designed for the same assessment objectives (using the same Question Set) that the results can be comparable with each other and used for longitudinal studies. Thus, the assessments with same objectives are the focus of this section, besides the special peer assessment, which considers the evaluation for each peer as different objectives resulting in more complicated analysis pattern. Apart from defining an assessment, the assessment space provides a more useful way of how to analyze the data and present a useful defined assessment report. Different variation of assessment space can be created with combination of dimensions according to assessment purpose besides the space analyzed below.

4.8.1 Individual Single Assessment in Individual Space

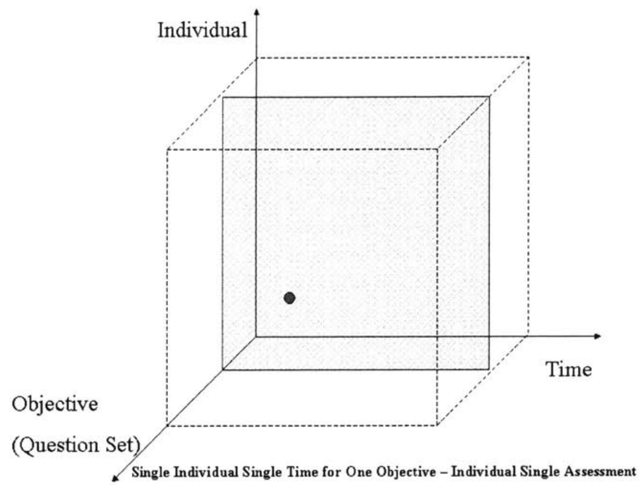


Figure 4-4: Single Individual Single Time for One Objective – Individual Single Assessment

Individual Single Assessment - This assessment is used to get feedback from each individual at a specific time for some objectives, such as Pre-course Evaluation.

4.8.2 Individual Series Assessment in Individual Space

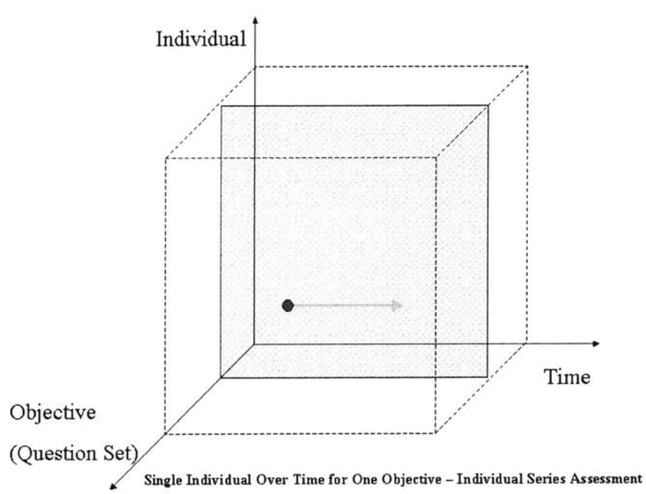


Figure 4-5: Single Individual Over Time for One Objective – Individual Series Assessment

Individual Series Assessment – In the assessment space of individual, if the initial assessment is carried out over time for a same objective, a Series Assessment can be created for the same assessment context for an individual. Individual Series Assessment can be used to monitor each individual's understanding of knowledge, learning and interaction process, and the progress of performance, such as Series Self Assessment, or used to track the change of feedback or evaluation for others, and the answering behavior, such as Series Peer Assessment.

4.8.3 Team Single Assessment in Individual Space

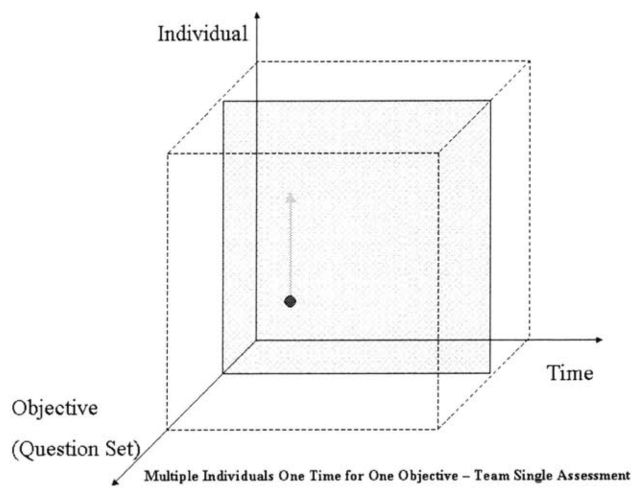


Figure 4-6: Multiple Individuals One Time for One Objective – Team Single Assessment

Team Single Assessment – The data and information got from the Individual Single Assessment at one time for one objective can be used to analyze along the Individual Participant Dimension, then the cumulative statistic results of the team can be generated for Team Single Assessment to reflect the feedback from the whole team at a specific time, such as Team Summative Report.

4.8.4 Team Series Assessment in Individual Space

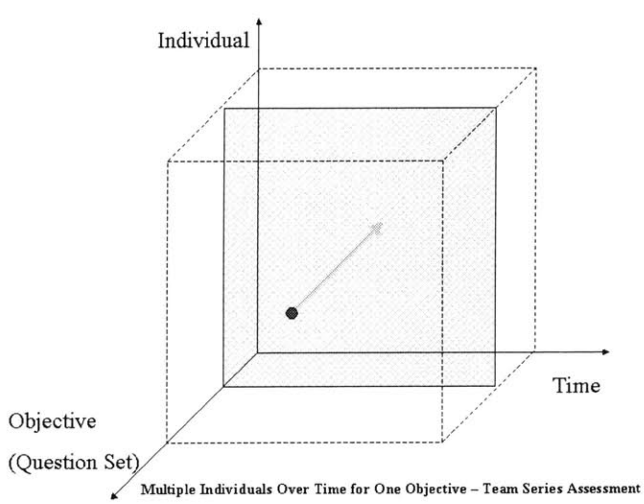


Figure 4-7: Multiple Individuals Over Time for One Objective – Team Series Assessment

Team Series Assessment: Combining the Individual dimension and Time dimension, the assessment can be developed as a Team Series Assessment in the space, which generates the results for multiple individuals over time for one assessment objective. Team Series Assessment is used to monitor the whole team feedback and interaction, group learning behavior and process throughout the course over time, such as Team Progressive Report.

4.8.5 Team Single Assessment in Team Space

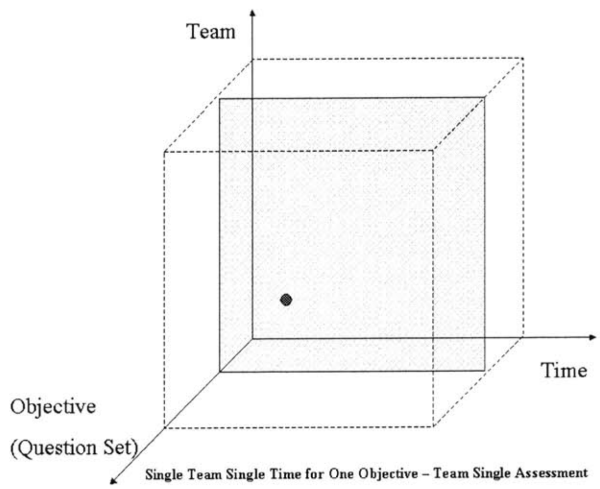


Figure 4-8: Single Team Single Time for One Objective – Team Single Assessment

Team Single Assessment: When the participation dimension changes to Team participant dimension, each point of the space represents the assessment of a whole single team for one objective at a point of time. Team Single Assessment can be viewed from the previous Individual assessment space and the Team assessment space in different perspective.

4.8.6 Sampling Assessment in Team Space

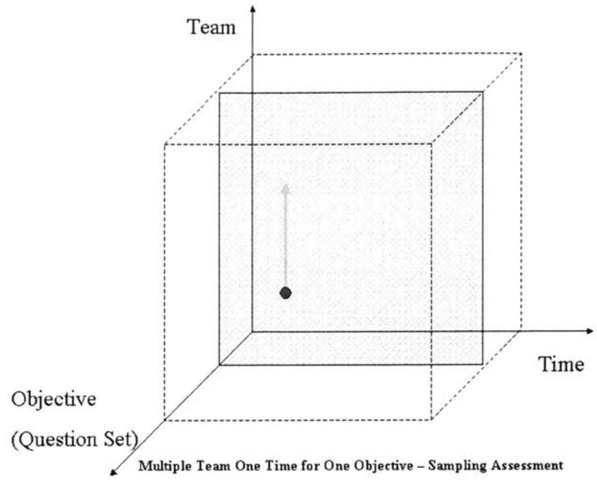


Figure 4-9: Multiple Team One Time for One Objective – Sampling Assessment

Sampling Assessment: To get more comprehensive and completed understanding about a target objective, evaluator may choose different sample groups to have same assessment. Sampling Assessment can derive from the initial team single assessment by accumulating the results along the Team dimension. From these results, evaluator can identify different sample groups' preferences and responses for one objective at a time and compare their understanding for the same objective, such as in Peer Assessment different sub teams' evaluation and feedback for the same person (as target objective) at a specific time of each team after he/she has joined the collaborative learning within the sub teams.

4.8.7 Team Series Assessment in Team Space

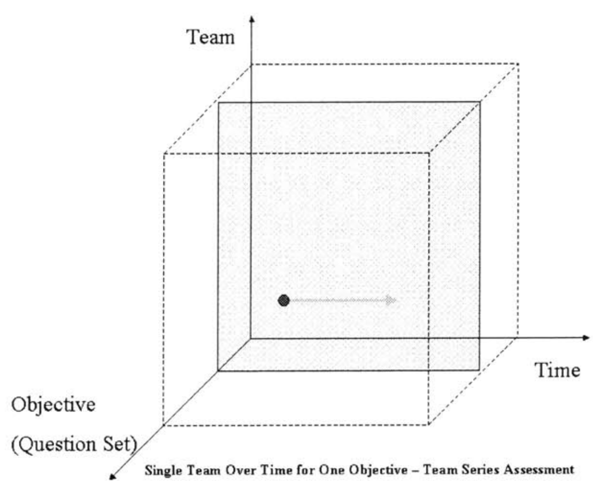


Figure 4-10: Team Over Time for One Objective – Team Series Assessment

Team Series Assessment: Implementing several Team Single Assessments within the same assessment context of the same team along the time, instructor can collect and analyze the data for one objective from a team perspective in different period of the learning process. That can be used to track the group feedback, learning behavior and progress throughout the course, such as the Series Team Assessment, Series Leader Assessment, Series Facilitator Assessment and the evaluation results of team for the same individual at different stages through Series Peer Assessment. The Team Series Assessment can also be viewed from either Individual space or from Team space in different perspective.

4.8.8 Team Collective Assessment in Team Space

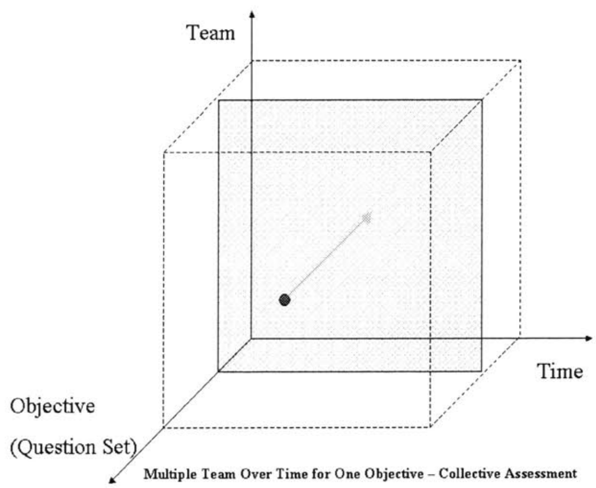


Figure 4-11: Multiple Team Over Time for One Objective – Collective Assessment

Team Collective Assessment: With same assessment context and objective, if a series of assessments go for different teams (sample groups) at different points of time, a Team Collective Assessment can be created to collect comprehensive data and generate a team collective report. The collective report shows different learning teams' responses for the same objective through a period of time, such as different sub teams' feedback to the same individual in Series Peer Assessment through the collaborative learning process.

4.8.9 Flexible Peer Assessment in Collaborative Learning Assessment Space

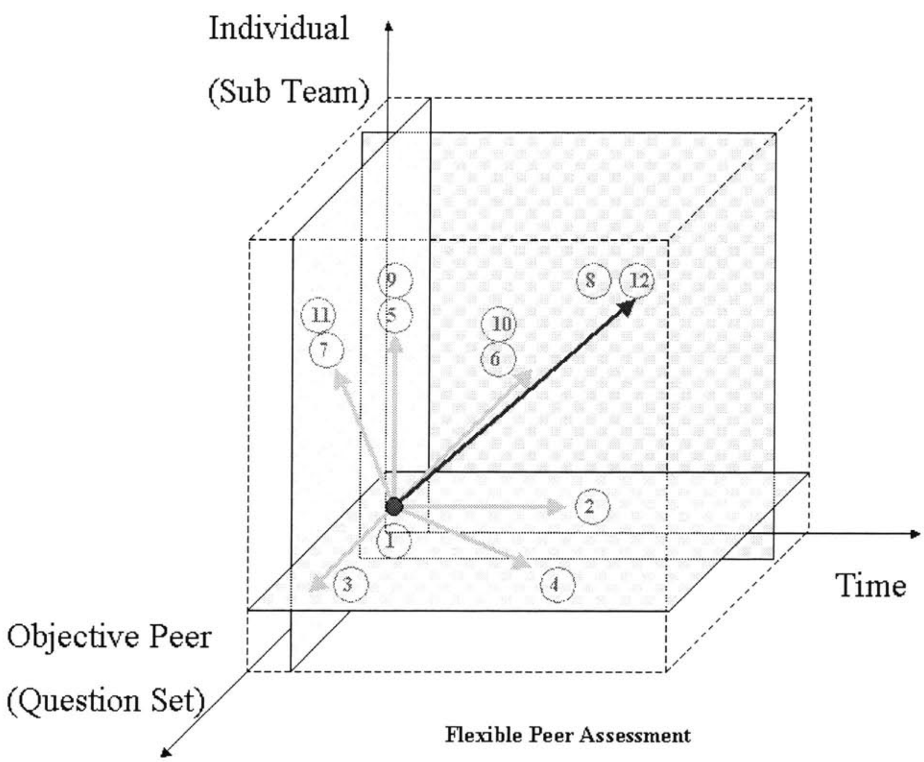


Figure 4-12: Flexible Peer Assessment Space

Peer Assessment is a special kind of assessment for each team member to evaluate other peers during the interaction of collaborative learning. Unlike most of the assessment contexts that have only one objective for the same series assessment stated above, it uses peers as different objectives in Objective dimension, i.e., each objective peer has a specific Question Set (implemented in CLASS system) for the peer's assessment and all the members will take different Peer Assessment for each peer. Moreover, as each individual may work with different sub team for each assignment or project during the whole learning process, it is more valuable to get the evaluation results of each sub team for a member over time. Thus, it turns out to be very complicated in Peer Assessment that involves relationships of peer-to-peer, peer-to-sub team, peer-to-global team, sub team-to-peer and global team-to-peer and combines the factor of time and accumulation, when reported in the analysis space of system. However, the Learning Assessment Space as a useful instrument makes the relationships quite clear and helps the assessment designer to understand assessment models. In the Figure 4-12, a flexible Peer

Assessment model can be generated and presented very clearly in Assessment Space to fulfill the following tasks from different perspectives:

1. Individual (Sub Team) Evaluate Same Peer at Single Time Point
2. Individual (Sub Team) Evaluate Same Peer Over Time
3. Individual (Sub Team) Evaluate Different Peers at Single Time Point
4. Individual (Sub Team) Evaluate Different Peers Over Time
5. Single Team Evaluate Same Peer at Single Time Point
6. Single Team Evaluate Same Peer Over Time
7. Single Team Evaluate Different Peers at Single Time Point
8. Single Team Evaluate Different Peers Over Time
9. Multiple Sub Teams Evaluate Same Peer at Single Time Point
10. Multiple Sub Teams Evaluate Same Peer Over Time
11. Multiple Sub Teams Evaluate Different Peers at Single Time Point
12. Multiple Sub Teams Evaluate Different Peers Over Time

4.9 Collaborative Learning Assessment Matrix

To realize the multidimensional assessment space in the real computer-supported system and generate various statistical assessment reports for the instructor, Collaborative Learning Assessment Matrix can be created to map the multi-dimensional space into a realizable 2D space representation. Every matrix presents a kind of relationship between every factor of selected two dimensions in the space. Each element in the matrix stands for a specific initial assessment in the assessment space for an individual or a team, and can be accumulated along different dimension to get a derived assessment. For example, in Individual Assessment Matrix, each element of Individual Single Assessment can expand to Team Single Assessment along Individual Participant dimension and extend to Individual Series Assessment over Time dimension; changing along both dimensions it is synthesized to Team Series Assessment. The following figures show some sample assessment matrixes that have been designed in CLASS (Collaborative Learning Assessment Support System) in this research. From these matrixes, useful analysis reports can be generated to inform the instructor about effectiveness of the collaborative learning. Collaborative Learning Assessment Matrix is applicable mapping and instantiation of Assessment Space.

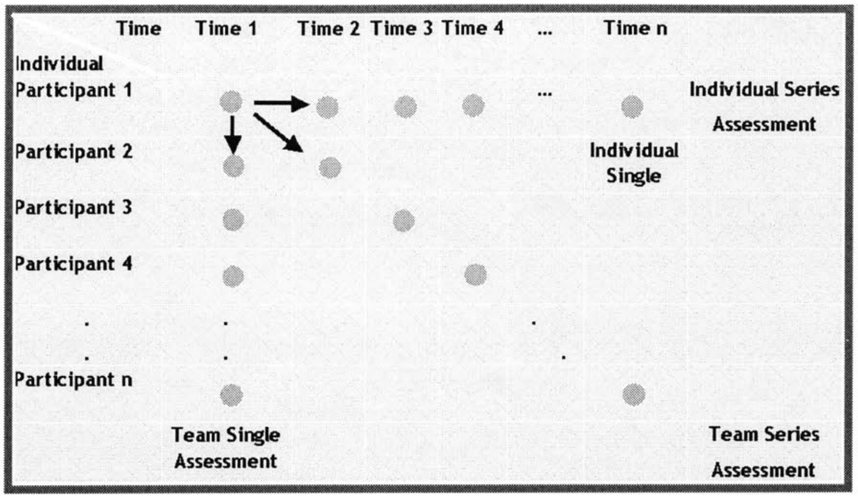


Figure 4-13: Individual Assessment Matrix (Same Objective)

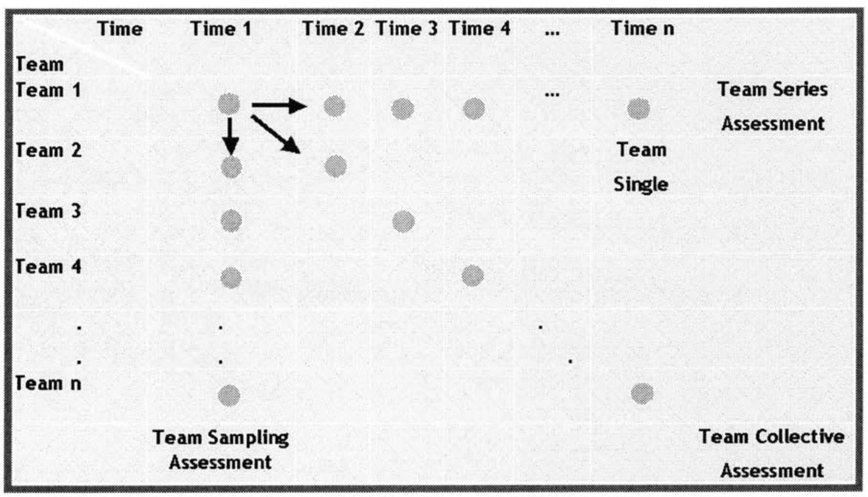


Figure 4-14:Team Assessment Matrix (Same Objective)

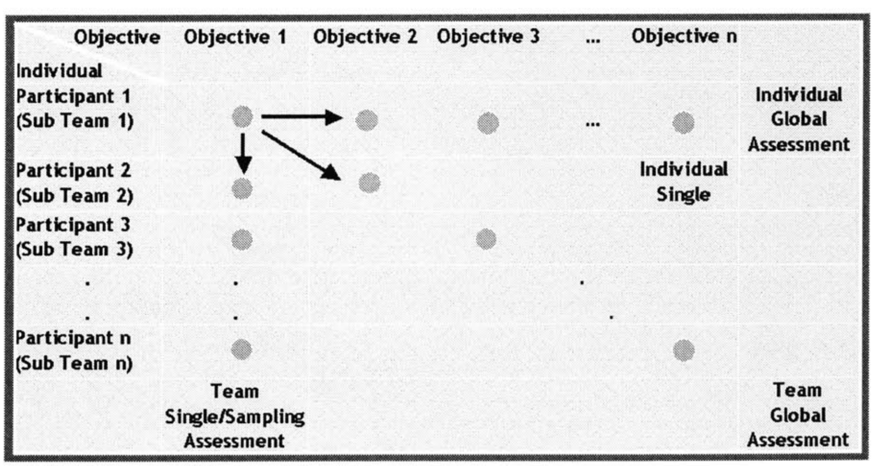


Figure 4-15: Peer Assessment Matrix (Different Objectives)

4.10 Collaborative Learning Effectiveness and Team Health Assessment Focus

To assist instructor to achieve assessment targets and designer to implement learning assessment system, Collaborative Learning Assessment Model, Multi-Dimensional Assessment Space and Assessment Matrix have been developed through the research as powerful instruments to understand the assessment environment. In summary, the Learning Effectiveness and Team Health Assessment designed and implemented in the collaborative environment are focusing on three aspects, learning, performance and satisfaction as listed below:

- Learning
    - Individual Learning
    - Team Learning
    - Organizational Learning
- Performance (Evaluated from Internal Evaluation or External Validation)
    - Individual Understanding of Knowledge and Improvement of Skills
    - Individual and Team Learning Process and Progress
    - Individual and Team Goal Achievement and Deliverables
    - Contribution to Teamwork and Behavior in Collaborative Learning
    - Learning Effectiveness and Collaboration Efficiency
- Satisfaction
    - Individual Satisfaction
    - Team Satisfaction
    - Process Satisfaction
    - Technology Satisfaction

Chapter 5 Computer-supported Collaborative Learning Assessment Support System (CLASS) Design

5.1 Traditional Assessment Approaches and Constraints

Questionnaire is an important means for people to gather information about other persons' beliefs, understanding, attitudes, behaviors, feelings, perceptions, motivations, or plans. Specially, in a collaborative environment, people need to collect information from the group to support group decision-making as well as evaluate the health of team collaboration or development. Traditionally, the assessment can be carried out and the data can be gathered in the following approaches:

- **Self Reports** (from participants and control group members):
  - Diaries or Anecdotal Accounts
  - Journals
  - Checklists
  - Rating Scales
  - Written Questionnaires
  - Personal interviews

- Telephone interviews

- **Products** (from participants):
  - Tests
    a. Supplied answer (essay, short response and problem-solving)
    b. Selected answer (multiple-choice, true-false, matching and ranking)
  - Samples of work and deliverables

However, the traditional approaches have some important constraints and disadvantages for current learning assessment, especially for the collaborative teaching and leaning in distributed environment:

For participants:

- Traditional approaches have time and spatial constraints that the participants need to finish the questionnaire within given time in specific place, such as personal interview and written questionnaire.
- Traditional approaches are hard to control the quality of data that can be obtained. At least two considerations are involved. The first is the *response rate*, the chief index of data quality in a survey because it defines the extent of possible bias from non-response. A low response rate calls into question any conclusions based on the data. The second aspect besides response rate is the *accuracy and completeness of responses* to questions. A personal interview or telephone interview makes it easier to build rapport between interviewer and respondent, motivating the respondent to give full and accurate answers, whereas written questionnaire generally falls short.
- Traditional questionnaires cannot be too long or take too much time, such as written questionnaires with generally no more than 12 pages or 125 individual responses.
- Traditional approaches do not allow participants to *correct misunderstandings or answer questions* that the respondent may have, such as in interview and written questionnaire.
- Traditional approaches do not allow participants to review and compare their previous responses after submit the answers.
- Traditional approaches sometimes do not make the respondents to have a feeling of anonymity that encourages open responses to sensitive questions, such as personal interview and telephone interview.

- Traditional approaches can bring the influence of potential *interviewer bias*, which is hard to minimize in telephone and personal interviews.
- Traditional approaches are lack of ability to use visual aids and interaction tools, thus too complex questions are impossible to ask.
- Traditional approaches seldom integrate the guidance of pedagogical framework and educational theories.

For organizers:

- Traditional approaches have relatively high cost and long process, which depends heavily on the geographic coverage required by the study, such as face-to-face interviews and handed-out questionnaires.
- Traditional approaches have limited availability for the distributed participants to access the assessment, manageability for the assessment groups and flexibility for assessment schedule.
- Traditional approaches are hard for the organizer to reuse the questions and assessment for different groups of participants in written format.
- Traditional approaches make the changes about the style, layout, and questions of the questionnaire difficult if they have been made out.
- Traditional approaches are lack control of question order and control of the context of question answering, specifically, the presence of participants in the written questionnaire.
- Traditional approaches are weak at control of response rate, completeness of answers and participation of distributed participants.
- Traditional approaches have no capability for post processing after data collection, such as data clearing, data analyzing and assessment reporting, which require additional time and process.

5.2 Electronic Collaborative Learning Assessment and Advantages

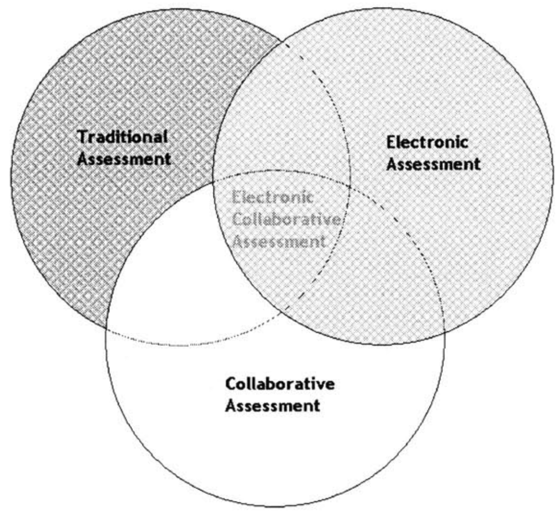


Figure 5-1: Assessment Schema

Figure 5-1 shows the rough schema on assessments. Traditional assessment and electronic assessment have different modes of data collection, data analysis and report generation. Electronic assessment heavily utilizes the Internet and database technology to facilitate questionnaire design, creation, presentation, participant management, respondents' invitation, responses storage, as well as result analysis and reporting. Collaborative assessment is the questionnaire specially used in collaborative environments with multiple teams and members, while Electronic Collaborative Assessment is defined to be the electronic assessment for collaborative learning in the distributed environment. Electronic Collaborative Assessment has almost all the advantages of the traditional modes while getting rid of their disadvantages:

- The most apparent advantage of electronic assessment should be its extremely low cost, time saving for the whole process, and convenience for the participant's access with just a standard browser.
- Electronic assessment can be available for the distributed participants without any geographic constrains through Internet and wireless network services, with development of the web and communication technology.
- Electronic assessment and survey can be carried out ***anytime anywhere*** with flexible schedule control.

- The questions and assessment contexts can be dynamically generated, saved, updated and reused for different teams or courses.
- Electronic assessments have great flexibility to control questions, assessment contexts and the ability to control the contexts of question answering.
- After collecting and storing all the data from participants, system can generate different reports and statistics analysis according to the requirement conveniently.
- Electronic assessment can provide abounded means for visual aids, like illustrations, graphs, even audio and video, with technology support.
- Electronic collaborative assessment reduces potential interview bias.
- It's easy to control the anonymity for answering and reporting that can make respondents to have a great feeling of anonymity.
- Various multi-dimensional assessment contexts, assessment space and matrixes can be implemented flexibly in electronic assessment, based on developed pedagogical framework and theories.

The organizers (instructors) do not really need to own and maintain a web server, application server and DB server to conduct an assessment; rather, they can utilize available service providers to carry out their willing assessment or surveys. The participants (students) only need a standard browser of traditional desktop, laptop or of mobile devices, such as PDA or Web-enabled Phone wireless network access, to take any collaborative learning assessment conveniently at anytime anywhere.

Table 5-1 summarizes and compares the advantages and disadvantages of three main traditional assessment approaches with electronic assessment.

Table 5-1: Summary Comparison of Different Assessment Data Collection Approaches

Dimension of Comparison	Written Questionnaire	Personal Interview	Telephone Interview	Electronic Assessment
Cost	Low	High	Moderate	Lowest
Data quality				
Response rate	Low	High	Moderate to high	High
Respondent motivation	Low	High	High	Low, but should have solutions
Interviewer bias	None	Moderate	Low	None
Sample quality (response rate, completeness)	Low, unless high response rate	High	Moderate to high	Highest, easy to control
Possible interview length	Short	Very long	Long	Longest
Ability to clarify and	None	High	High	High

probe				
Ability to use visual aids	Some	High	None	High
Speed	Low	Low	High	Highest
Interviewer supervision	None	Low	High	None, but may be monitored
Anonymity	High	Low	Low	High
Ability to use computer assistance	None	Possible	High	Whole process
Dependence on respondent's reading	High	None	None	High
Control of context and question order	None	High	High	Moderate

5.3 CLASS System Advantages

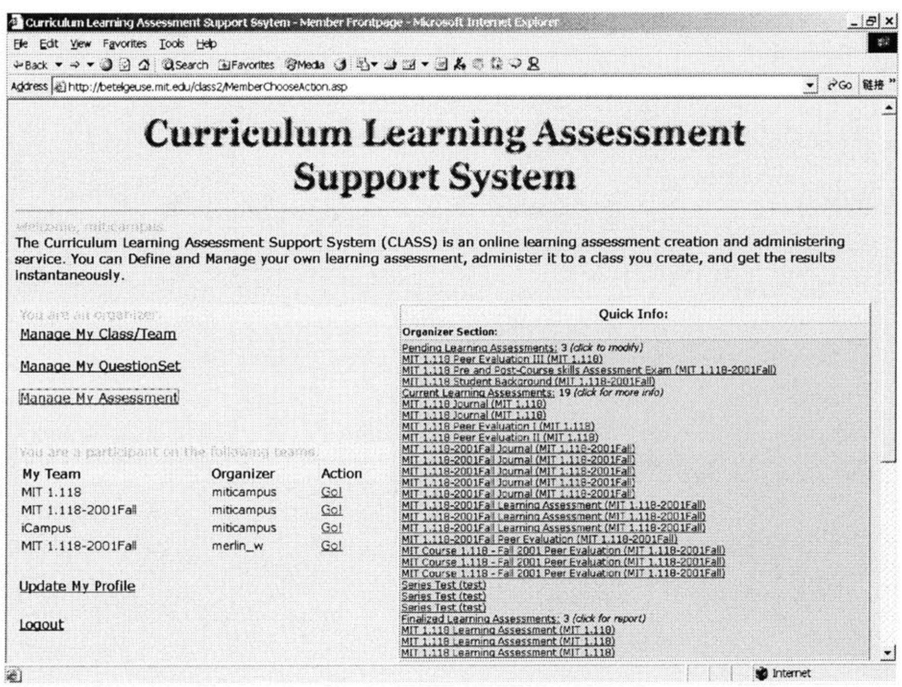


Figure 5-2: Collaborative Learning Assessment Support System (CLASS)

Collaborative Learning Assessment Support System (CLASS) is an easy-used web-based system, which creates a comprehensive multi-dimensional assessment space with pedagogical framework and educational theories' support. It provides full functionality of Class and Member Management, Question Management, Assessment Management, Participation Management and Report Management to support various collaborative learning assessment contexts during the whole learning and teaching process in the distributed collaborative learning environment. The convenient services are implemented for both the organizers and participants from different perspectives. This system is used to conduct self-evaluation of students for self-improvement, to guide students through their work at a level-appropriate pace in different phases, to evaluate student performances based on their perceived contribution to the teamwork, to report and analyze students' learning behaviors throughout the course, to improve distributed team learning effectiveness and performance, and to maintain team health. This system has the following advantages over the traditional electronic assessment systems:

- Pedagogical framework and educational theories support
- Multi-dimensional assessment model embedded and comprehensive assessment space realization
- Completed collaborative learning assessment process and functionality
- Easy-used web-based thin client system
- Multi-tiered Application Server architecture
- Flexible question and assessment creation and presentation
- Effective team /participant management and participation control
- Dynamic multi-dimensional assessment data analysis and report generation
- Easy assessment access and simple taking process for distributed learning team members
- Help to minimize the assessment errors and biases

5.4 System General Architecture

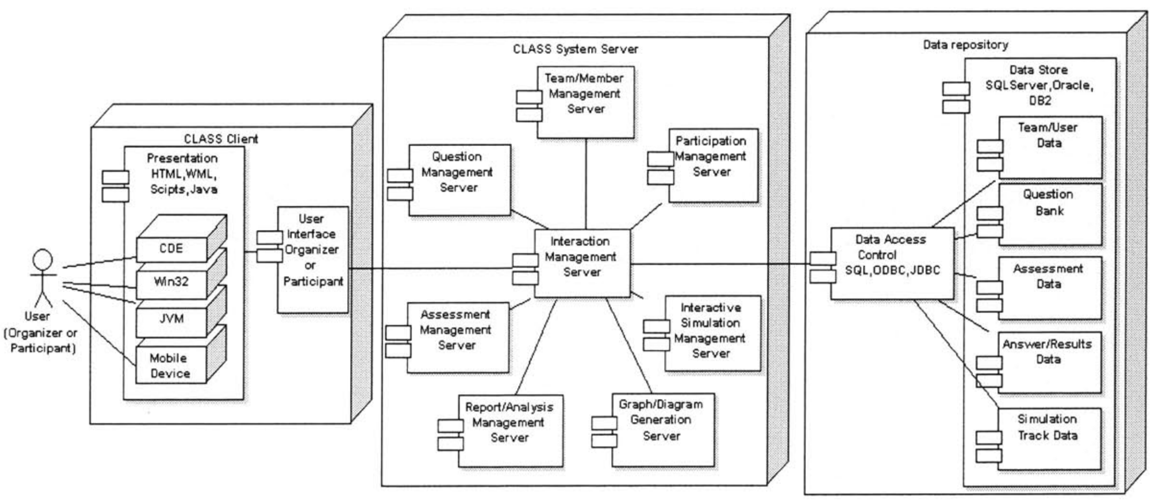


Figure 5-3: CLASS System General Architecture

Considering flexibility, scalability, reliability and performance of CLASS system, and development process of this system, a multi-tiered thin-client web-based Application Server architecture has been adopted to implement the Collaborative Learning Assessment Space in the

Virtual Collaborative Learning Environment. In multi-tiered Client/Server architecture, presentation logic, application logic, data logic have been separated into different tiers to provide high scalability and robustness for the system. All application logics and processes run on the Web Application Server (CLASS System Server), while CLASS Server interacts with Data Repositories (maybe various Database Servers) to retrieve, allocate and update all resources, interprets, generates and sends the results to CLASS Clients in different presentation formats, such as HTML or WML, which depend on multiple client devices and requirements through wired or wireless network. Users can use multiple client devices to access the assessment system services and data without considering the network and server environment with appropriate permissions. The general architecture is shown in Figure 5-3, which is actually a five-tiered architecture with two more tiers than the traditional tree-tiered architecture.

Separating client side's logic into User Interface layer and Presentation layer enables the system to generate a uniformed User Interface without considering the final presentations of the data, which separates data with data representation. According to different user devices and presentation requirements, the system can interpret the results processed in CLASS Server and interfaces into different formats, styles and presentations that can be handled by different client devices, such as HTML for desktop web client and WML for WAP-supported mobile phones.

On the data repository side, Data Access Control layer and Data Store layer form the backend system of CLASS. Data Access Control layer make the system data-source-platform independent, that is, the system's backend data stores can be any kinds of databases, such as SQL Server, Oracle or DB2, and enable the system to interact with multiple data stores (data stored in different kinds of databases) for the processing via Database Drivers and Connectors Pool like ODBC or JDBC drivers. Moreover, Data Access Control layer increases the system performance and robustness by using Connection Pools that enhance the system concurrent DB access capability, and increases the system connectivity with other backend systems in the Virtual Collaborative Learning Environment.

5.5 System Components and Functional Model

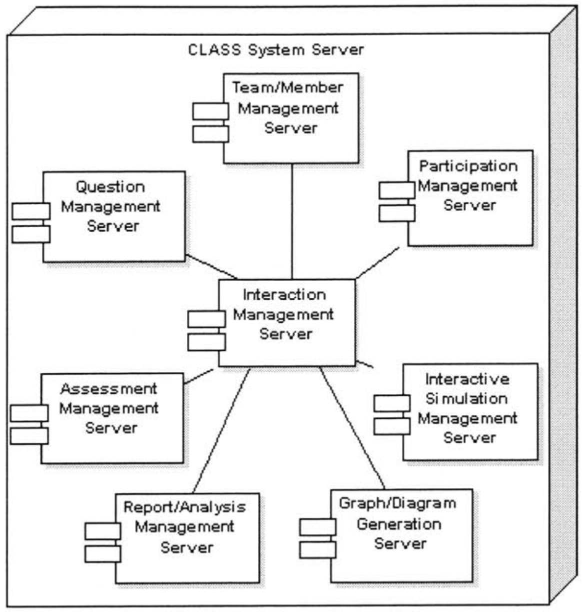


Figure 5-4: CLASS System Components

There are mainly eight components in CLASS System Server to form the functional architecture of collaborative learning assessment space: Interaction Management Server, Team/Member Management Server, Question Management Server, Assessment Management Server, Report/Analysis Management Server, Participation Management Server, Graph/Diagram Generation Server and Interactive Simulation Management Server. Most of the server components are focusing on the work of organizer for learning assessments and few components are working for participants based on the principles that make the participant's work as simple as possible and make the client side as thin as possible.

5.5.1 Interaction Management Server

Interaction Management Server acts as the manager and controller of the whole system and maintains the interaction environment. It monitors the interaction between the clients and server, gets requests from the clients, controls the information flow between other server components to process the tasks, and send results to the clients. It manages the interactions of other server components within CLASS Server as well as the interactions between CLASS Server and other Spaces in Virtual Collaborative Learning Environment.

5.5.2 Team/Member Management Server

Team/Member Management Server provides functionality to create class and sub teams within a class, invite new participants to specific class and team, and manage the class participants, which form the basic collaborative learning environment for assessments.

- Class Management: create, update and delete class
- Flexible Sub Team Management: generate sub teams for special purpose during the collaborative learning process, such as different sub teams for assignments and projects
- Participant Management: invite class member for specific class and sub team, delete participant, modify participant information, and manage the members' team assignment

5.5.3 Question Management Server

Question Management Server provides functionality of Question Set and Question management, which forms the contents for learning assessments.

- Create and manage Question Category for easy manipulation of questions
- Create and manage Question Set for specific assessment creation
- Conveniently generate questions online and dynamically output contents as preferred formats and styles (Single Choice Question, Multiple Choices Question, Numerical Choice Question, AnswerBar Question, AnswerBox Question, List Question, Rating Question)
- Modify and check generated questions in WYSIWYG style
- Update and manage Question Bank of different kinds of Questions
- All Questions are stored in the Question Set, which can be reused for different learning assessments.

5.5.4 Assessment Management Server

Assessment Management Server provides functionality to create and manage learning assessments for different assessment contexts in the multi-dimensional assessment space. The assessments are generated according to the class requirements and learning process, using specific question set and designed schema.

- Multi-team multi-assessment management

- Create and manage different multi-dimensional assessment contexts in the system
- Create Single Assessment of specific Team using specified Question Set for a point of time
- Create Series Assessment by daily, weekly, monthly or any specific intervals automatically. Control assessment to be in a Series Assessment or not and specify assessment valid time and period
- Control permission of participant to review the answers to other previous assessments in the same Series Assessment
- Control anonymity of participants in assessment taking and assessment reporting process
- Abundant and flexible assessment properties control: valid period, assessment initialization and finalization status, access permission and privilege
- Invite the participants of existing teams/classes or new participants to join the assessment, send notification email conveniently or "push" to the WAP phone in future, register qualified users automatically, generate action code for secure access and dynamically update information in the participant's Information Center pages

5.5.5 Report/Analysis Management Server

Report/Analysis Management Server has abundant functionalities of statistics analysis and reporting from multiple perspectives in the Assessment Space described in previous chapter. After collecting the data through the system, it clears the data, analyzes the data and presents the useful feedback and evaluation results in different report styles as required to help instructor identify barriers of learning effectiveness and collaborative learning behavior of individual and team.

- Dynamically create multi-dimensional assessment Report Matrixes, by combining different dimensions of Learning Assessment Space, such as Individual Assessment Matrix, Team Assessment Matrix and Peer Assessment Matrix
- From the Report Matrix, different assessment reports can be generated, such as Static and Longitudinal Report for Individual or Team, Team Sampling Report and Team Collective Report

- Track individual and team interactive learning responses and behavior through Interaction Report and Progressive Report, cooperated with Interactive Simulation Management Server
- Statistical analysis (Frequency, Min, Max, Mean, Mode, Standard Deviation, Distribution and Behavior Change Over Time) for quantitative questions
- Generate various dynamic Bar/Column Chart and Dot/Line Graphic for Statistic Report (Java Servlet) on fly to show statistic results graphically and analyze the change of individuals/teams behavior visually in Single Assessment or in Series Assessment, working with Graph/Diagram Generation Server
- Sort and search assessment reports by various criteria such as by time, by individual, by group, by objective or by participants' location

5.5.6 Participation Management Server

Participation Management Server helps instructors to monitor and manage the class member's participation of the learning assessment.

- Monitor individual and team response rate to each question and the whole assessment
- Dynamically generate Participation Report for each assessment
- Conveniently send notification and reminder to participant about missing questions and incompleteness of assessment

5.5.7 Graph/Diagram Generation Server

Graph/Diagram Generation Server is a powerful tool for the system to generate all kinds of graphic presentations on server side in order to visualize the concepts and results in a more direct way. Many other servers interact with Graph/Diagram Generation Server to created useful result in different context, such as Report/Analysis Management Server and Interactive Simulation Management Server. Moreover, it overcomes the defects for graph printing brought by traditional Java Applet solution by using Image Encoder and server-side Java technology like Java Servlet to create printable graphic formats.

- Generate various kinds of dynamic chart styles on fly: Bar Chart, Column Chart, Dot Graph, Line Graph and Dot-Line Graph

- Easily integrated and interact with other components to generate Statistic Diagram, Distribution Diagram, Series Diagram and Legend Diagram
- Control Graphic Customization and abundant Diagram Generation Properties over net from client side, such as Chart Style, Color, Background, Data String Visibility and Data Table Visibility
- Output graphs and diagrams in printable formats
- Effective and fast server-side graph generation on fly

5.5.8 Assessment Management Server for Participant

As CLASS should support invited participants to access assessments easily and make responses conveniently at anytime anywhere, the client side are designed as thin as possible for multi-tiered architecture and functionalities of participant are as simple and straightforward as possible. Assessment Management Component for participant provides functionality to manage and take assessment easily.

- Dynamically update participant assessment management page after any relative change in assessment space
- Manage the participant's own available assessments in different teams of multiple classes
- Access and take available assessments
- Review and update their responses to old assessments in the validated period
- Control review of answers to other previous assessments in the same series

5.6 System Assessment Context

CLASS system provides abundant services for both the organizers and participants from different perspectives. There are lots of rules and protocols of interactions between the organizers and participants underneath to control the communication and assessment process for assessment creation, assessment taking and analysis reporting. This system provides an interaction environment for different assessment contexts can be defined in multi-dimensional Assessment Space and support all formats of assessment questions. These assessments contexts include: Self Assessment, Peer Assessment, Team Assessment, Leader Assessment and Facilitator Assessment. All of them can be built and reported from quantitative perspective (Integrated Survey) or from qualitative perspective (Learning Journal), as well as from single time point perspective (Single Assessment) or from longitudinal/periodical perspective (Series Assessment).

The assessment results can be analyzed from various Assessment (Report) Matrixes, such as Individual Assessment Matrix, Team Assessment Matrix and Peer Assessment Matrix mapping different dimension combinations of Assessment Space. From these assessment matrixes, the instructor can get Individual Single Assessment Report, Individual Series Assessment Report, Team Single Assessment Report, Team Series Assessment Report, Team Sampling Assessment Report, Team Collective Assessment Report, Individual Global Assessment Report (individual evaluates all the peers in the global team) and Team Global Assessment Report (team evaluate all the peers in the global team) in Peer Assessment Matrix. These assessment and report contexts provide instructor with useful information to track team collaborative learning behavior and feedback, to help identify and overcome the barriers to collaborative learning effectiveness and team health.

5.7 System Processes for Effective Collaborative Assessment

5.7.1 Effective Collaborative Assessment Process

CLASS system carries out collaborative learning assessment in a computer-supported virtual environment by implementing an effective evaluation process of assessment. Normally the assessment process can be thought of as having eight main phases as shown in Figure 5-5:

- Clarify goals and objectives of assessment
- Determine and manage sampling group
- Design and create assessment context
- Develop assessment questions
- Match questions with appropriate assessment context and information gathering techniques
- Collect data
- Analyze data
- Provide information to interested audiences

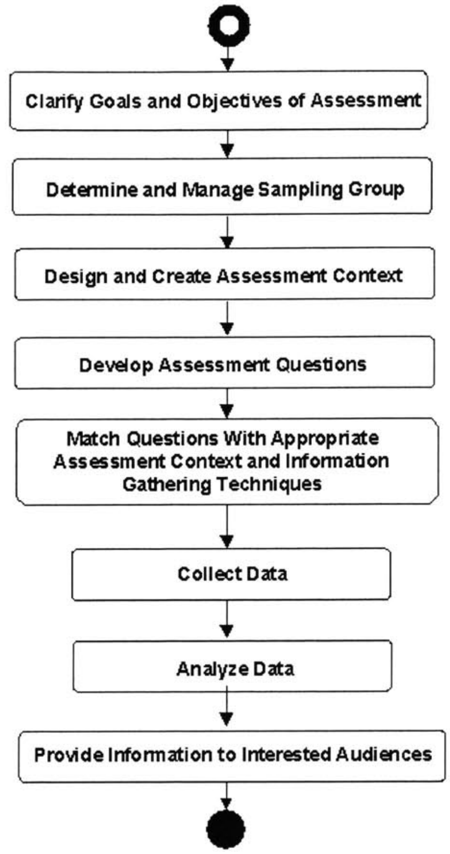


Figure 5-5: Collaborative Learning Assessment Process

The procedures can be described in more details:

1. Clarify goals and objectives of assessment
    - Clarify goals and objectives of assessment in different stages of collaborative learning, such as objectives for Self Assessment, Peer Assessment, Team Assessment and Facilitator Assessment
2. Determine and manage sampling group
    - Identify and involve key stakeholders and audiences of the assessment, such as students as participants and instructors as organizer
    - Determine sampling group structure and create teams or sub teams for the class
    - Invite participants for the class and teams
3. Design and create assessment context
    - Analyze assessment space dimensions and choose appropriate assessment dimensions to create assessment space for the collaborative learning

- Describe the interaction and environment to be evaluated
- Build up the assessment context and decide information-gathering techniques, such as Single or Series Assessment, Quantitative or Qualitative Data Source

4. Develop assessment questions

- Formulate potential evaluation questions of interest to all stakeholders and audiences, targeting different learning effectiveness and health variables
- Categorize, prioritize or eliminate questions
- Determine whether to make use of existing question set, questions or scales
- Build question set for reuse
- Create the assessment questions with preferred formats and styles online, paying attention to question sequences, wording and scales

5. Match questions with appropriate assessment context and information gathering techniques

- Modify the assessment questions under different categories in each question set
- Design and create assessment for specific team using specific question set

6. Collect data

- Pretest the assessment in small yet representative respondents, so as to identify unforeseen problems on existing questions, to see whether it is necessary to add or eliminate questions or need to convert open-ended questions to close-ended ones
- Analyze the pretest results and make necessary adjustment to questions or assessment
- Publish the assessment and invite target team to take the assessment
- Decide data collection schedule and control assessment status, such as Pending, Initialization, Active, Finalization
- Collect data from all the participants
- Control the necessary clearances and permission and adjust assessment properties properly
- Check responses and data validation
- Monitor team participation and generate participation report to instructor

- Analyze participation report and send notification to participants about the missing questions or delay of participation

7. Analyze data

- Analyze data in iterative process
- Check raw data and prepare data for analysis
- Conduct initial analysis based on the assessment plan
- Conduct multi-dimensional analysis based on the multi-dimensional assessment space and assessment matrixes
- Calculate statistics results such as Choice Frequency, Min, Max, Mean, Mode and Standard Deviation of quantitative questions, Distribution of responses in a team and Behavior Change over time of individual learning

8. Provide useful information to interested audiences

- Integrated and synthesize statistical results and findings according to the instructor's requirement and assessment purposes
- Generate required diagrams for reports on fly, such as Statistic Diagram, Distribution Diagram, Series Diagram and Legend Diagram, in various kinds of chart styles, such as Bar Chart, Column Chart, Dot Graph, Line Graph and Dot-Line Graph
- Create assessment reports dynamically integrating useful statistical results, feedback for qualitative questions and vivid diagrams
- Generate Report Matrixes with various assessment reports from different perspectives that reflects defined Assessment Space and assessment objectives
- Manage assessment reports and search for required reports by specific conditions, such as time, individual, team, location and objective (question set)

5.7.2 CLASS System Assessment Process Activity Diagram with Swim Lane

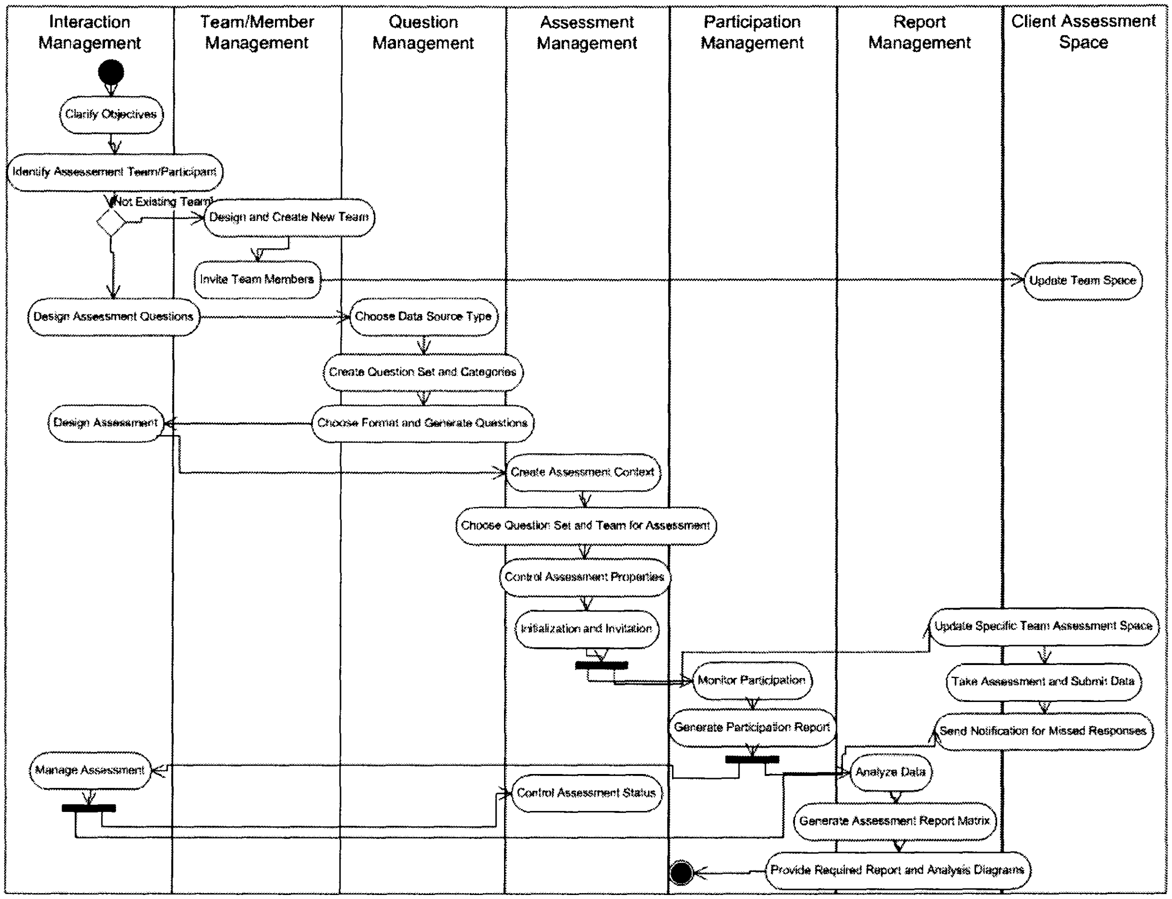


Figure 5-6: CLASS System Activity Diagram with Swim Lane

CLASS system implements the whole collaborative learning assessment process in a computer-supported virtual environment, which is accomplished by the collaboration of several CLASS server components described in the system architecture. Interaction Management Server controls the collaboration between different server components, the communication between different clients and servers, and interaction protocols between participants and organizers. CLASS System Activity Diagram with Swim Lane shown as Figure 5-6 clearly presents the main workflows and interactions between CLASS system server components to fulfill an effective assessment process. For all the assessment processes, the computer-supported assessment tools can increase the assessment flexibility and efficiency.

Chapter 6 CLASS System Implementation and Evaluation

6.1 System Data Modeling

A Collaborative Learning Assessment Support System (CLASS) has been implemented as Learning Assessment Space in the virtual collaborative learning environment. As CLASS system is designed as a multi-tiered web-based Application Server architecture, all application logics and assessment processes are running on the Web Application Server (CLASS System Server), while the CLASS Server interacts with back-end Data Repositories (maybe various Database Servers) to retrieve, allocate and update all resources, to fulfill all the tasks. Therefore, the system is data-centric; system database design and data modeling are quite important for system implementation. Following sections give brief description about the system data modeling.

6.1.1 Entity Relationship (ER) Diagram

Figure 6-1 illustrates the conceptual data model that presents the entities, attributes of each entity and relationships between entities. Only important entities are shown here.

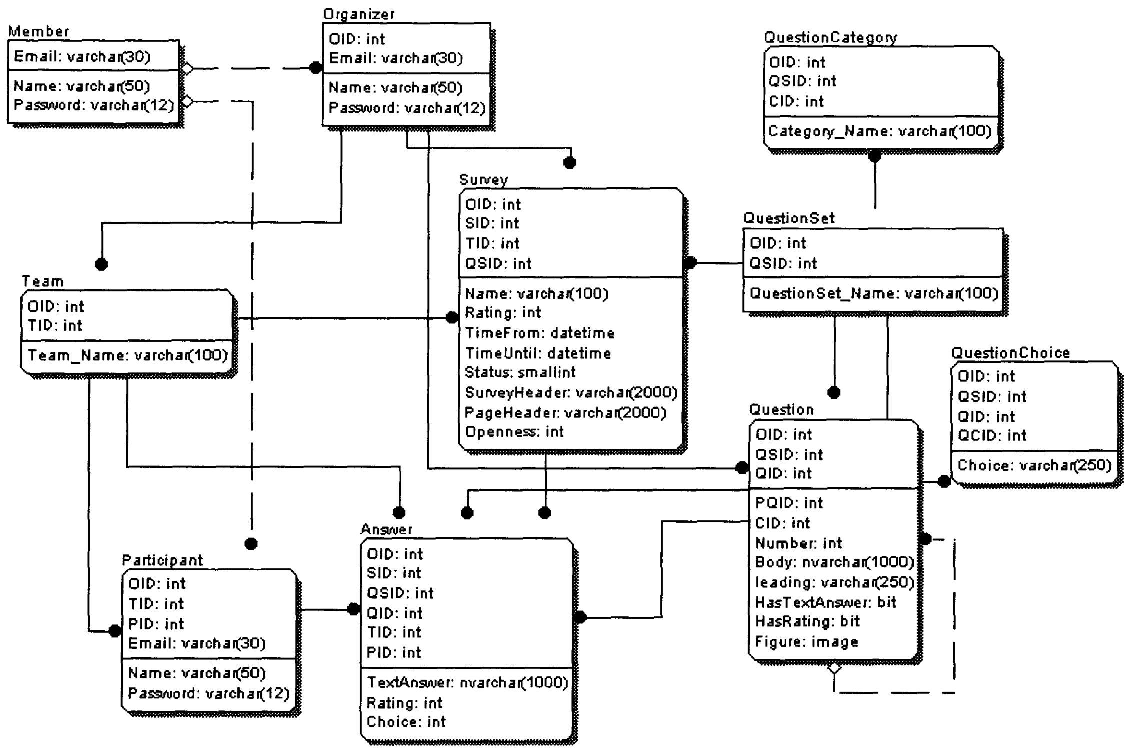


Figure 6-1: ER Diagram Of Conceptual Model

6.1.2 Business Rules /Relationships

Table 6-1 lists the main relationships between entities. Note that the Organizer is not included here, because any other entity (excluding Member) has many-to-one relationship with Organizer.

Table 6-1: Relationships Between Entities

Pair entities	Relationship
Member & Participant	One member of the system can be many participants of different teams, but one participant of a specific team must be a unique member in the system
Member & Organizer	One member of the system can be a organizer in the system and one organizer must be a unique member in the system
Participant & Team	One participant can belongs to only one team created by a organizer, while one team contains at lease one participant
Organizer & Team	One organizer can create and control many teams, but each team is managed by one organizer
Question & (sub) Question	One question might have many sub-questions, while one sub-question should belongs to just one question
Question & Category	One question should belong to one category, while one category might have many corresponding questions
Question & Question Set	One question might appear in many question sets, and one questions set should contain at least one question
Survey & Team	One Survey is taken by exactly one team, while one team might take various surveys (using different question sets)

Survey & Question Set	One survey uses exactly one question set for a objective, while one question set might be used in various surveys (taken by different teams)
Answer & Participant	One answer belongs to exactly one participant, while one participant can have many answers (in different surveys and answering different questions)
Answer & Survey	One answer belongs to exactly one survey, while one survey has many answers (answered by different participants, who answers a lot of questions)
Answer & Question	On answer belongs to exactly one question, while one question might have different answers (answered by different participants in different surveys)

6.1.3 Data Dictionary and Entity Analysis

This section briefly analyzes the important entities in CLASS system.

Member

Each user of the system, either an organizer or a participant, must be a registered member. Each member is uniquely identified by his email address, which is used when a user sign up as a new member and later sign in the system.

Each member must have a non-empty password for security.

A member might have two roles. He/she might be an organizer, administering his own teams and assessments. Besides, he/she might be affiliated to a number of teams, taking multiple assessments issued by other organizers.

Organizer

An organizer is a powerful member, who can fully manage all his/her assessments, classes, and questions. Each organizer can be identified by the organizer's ID and Email in the table Organizer.

An organizer can create and manage a number of classes or teams; for each team, he/she invites people to join via emails automatically generated by the system. The system will check to see whether the invited email belongs to a registered member or not.

If this email has not been registered, the system will send an email to that address with encrypted string in URL such that the receiver can register and join the team by clicking the URL in the email client program.

If this email belongs to a registered member, the system will check to see whether this member is already a participant of the target team; if not, the system will send an email to that address with encrypted string in URL so that the receiver can join the team simply by clicking the URL.

An organizer can create and manage a number of questionsets; for each questionset, he can create questions. Each question belongs to certain category, so that the organizer has to build a list of categories before he can create new question for the questionset, which can be reused for different assessments.

An organizer can create and manage a number of assessments. Each assessment has two basic components: the team/class and the questionset. An organizer can generate analysis report according to different requirement for evaluation and reporting.

Class/Team

A class/team is composed of a number of participants that construct the environment for collaborative assessment. Each team should belong to exactly one organizer, who specifies the email addresses of those people who ought to join this team. The system will take care sending emails and post-processing.

Participant

For thin client, a participant has not much work to do. Each user can sign up as a member, but not able to join any team before he receives an invitation email from certain organizer. After joining, he might also receive email from organizers to invite him to take assigned assessments.

Generally the email message contains a URL, which has an encrypted string (QueryString in HTML). Simply clicking the URL, the browser will take him to proper HTML page. After IIS receives such a request, the system will automatically register the user as a new system member, add the member as a participant to certain class/team, or prepare the assigned assessments for the participant to take. Actually a participant needs not to login the system frequently; he just checks his emails!

QuestionSet

A questionset is composed of a number of questions, which are ordered by their numbers. Generally these numbers do not need to be unique, nor do they need to be increased one by one. But the system strongly recommends such as good practice, and does provide a functionality to check the validity of numbers for all questions in one questionset.

Since each question should belong to certain category, a question set also contains several question categories.

There is a constraint to the questions concerning the categories: all questions should be grouped into categories, and all questions belonging to the same category should be ordered continuously.

In other words, the first group of questions belongs solely to one category, say, category A, and the second group of questions belongs solely to another category, say, category B, and so on. The system provides a mechanism to check for the rule.

QuestionCategory

For better understanding and management of the assessment questions, question categories are created to classify the questions. Each questionset may have several question categories, as different questionset has different nature of questions.

Question

Question table is vital to the whole system. It not only contains the question body, but also carries information on question presentation (how to show the question in the client side browser) and answer specification (how to limit user to submit valid answer only).

Currently each question might have unlimited number of sub-questions. Note a sub-question itself cannot be a parent-question. Column PQID stores the ID for the parent-question, thus PQID can not be the ID of the question of which the PQID is not null.

Column CID, Number, Leading and Body are related to question content and presentation, where CID is used to point to the question category to which the question belongs, and Number is used to arrange questions when displaying them in the browser. Note the system enforce a rule to group the questions in one questionset into categories.

Column Leading and Body store information content of the question. HTML codes are accepted so that attractive questions presentation can be achieved, although some limitations do exist to ensure the correct presentation of questions.

Column Leading is especially useful when the organizer need to display some extra information before the question body. Typically this feature can be used in the question that begins a new category, so that information specific to this category is shown before all questions belonging to the category are presented.

Concerning to the answer specification, current version supports several kinds of answers, such as comment or text answer, rating and multiple choice. For comment, participants need to type his answers; for rating, participants need to select a number ranging from 1 to maximum rating, say, 5; for multiple choice, participants should choose one from a number of choices.

These three kinds of answer specification can be combined in one question. So it is possible to design such a question that needs the participant to choose a rating number, select a choice, and then write some comments. Another feature worthy of nothing is that both parent-question and sub-question can have any combinations of these three specifications.

Column HasTextAnswer and HasRating are used to specify whether the question accepts comments and ratings. For multiple-choice, another table QuestionChoice is used to store all possible choices for one question. See QuestionChoice for details.

Note column HasRating only specifies whether the question needs the user to choose a rating from a range. The default minimum rating is always 1. In the real world, the maximum rating should be the same for all questions in one questionset. In our system, the maximum rating is stored in table Survey as a parameter of the survey.

Column HasFile determines whether this question allows the user to post or update files of acceptable formats to the system server as part of the answer.

QuestionChoice

Table QuestionChoice is used to store all choices for multiple-choice questions. Because of the master-detail relationship between table Question and QuestionChoice, one multiple-choice question can present unlimited choices for the participants to choose from.

Survey

A survey has two basic components: questionset and team. Besides, there are several important columns in table Survey.

Column Rating specifies the maximum rating number for all rating questions in the survey. See column HasRating in table Question for related information.

Column SurveyHeader records the information and describe the assessment context that should be shown before the participants begin to answer questions. Generally the purpose, some notes that the participants need pay attention to, privacy statement, and so on, should be displayed. Column PageHeader records the information shown in each page of the survey, because questions are displayed in multiple pages. Both SurveyHeader and PageHeader accept HTML codes so that they might seem attractive and rich in contents.

There are plenty of control properties for an assessment, such as "isInSeries" to determine whether an assessment is in a Series Assessment, "allowReview" to control the participants' permission to review answers to the previous assessments in the same assessment series and "isAnonymous" to control whether to collect the data from participants anonymously or show the assessment report in an anonymous way without participants' information to audiences.

Each assessment should have its valid duration. Column TimeFrom and TimeUntil record the beginning date and ending date for a survey, respectively.

Each survey has a status properties recorded in column Status. Status may be "pending", "current", or "finalized", which is important in that it controls actions that can be taken to the assessment. Before the date of TimeFrom, the status of the survey is "pending", and the organizer is free to modify its information, including adding, removing the possible participants, and changing questions. Once the date passes TimeFrom, the status of the survey changes to "current", and emails will be sent to participants to invite them to take this survey. URL with encrypted string is embedded in the email so that all the participant need to do is to click this URL in his email client program. During the effective period of the survey, the system will monitor to find whether there are participants who receive the email but have not taken the survey. Besides, the organizer can generate report on the survey at any time, although it is possible that not all participants have answered questions when he generates such an "incomplete" report. After the date passes TimeUntil, the status of the survey changes to "finalized", and no participant is allowed to take this survey. At that time, the organizer can produce final reports on the survey.

There is a constraint on organizer's ability to change assessment information according to its status. When the survey's status is "current" or "finalized", the organizer cannot make changes to the assessment, its questionset and its team.

Answer

Table Answer stores all the answers that all participants have given in all assessment. To uniquely identify each answer, the IDs of organizer, assessment, question and participant are just enough (can not be less), because the questionset and team info can be deducted from the relative information in assessment. But for the purpose of easy statistics, the IDs of questionset and team are still recorded. Table Answer has

Table Answer takes various defined answer formats related to the question, such as text answer, rating number and choice chosen. All these data are the resources for later statistical analysis, diagram and report generation.

6.2 System Functional Modeling and Features

Based on the system architecture designed in the previous chapter, CLASS system has been implemented with abundant functionalities for Team/Member Management, Question

Management, Assessment Management, Report/Analysis Management and Participation Management to support different collaborative assessment contexts during the whole teaching and learning process in the distributed collaborative learning environment.

The implemented main functionalities are categorized in different participation perspective of organizer and participant, described in the following sections and illustrated in screen dumps. More detailed design and functionality see reference (Wang Wei, 2001).

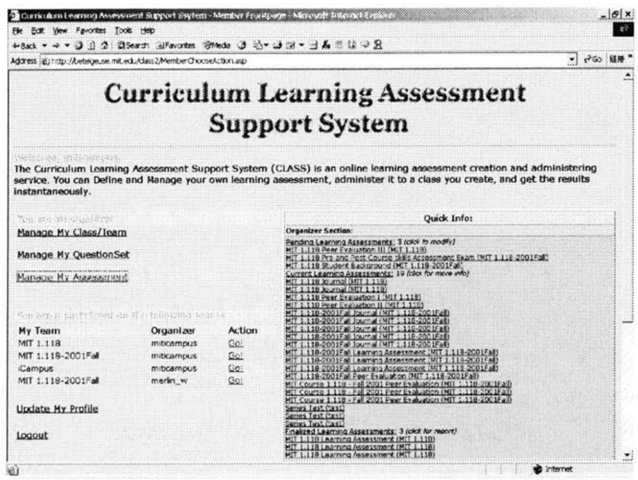


Figure 6-2: CLASS System Information Center

6.2.1 Organizer Functionality

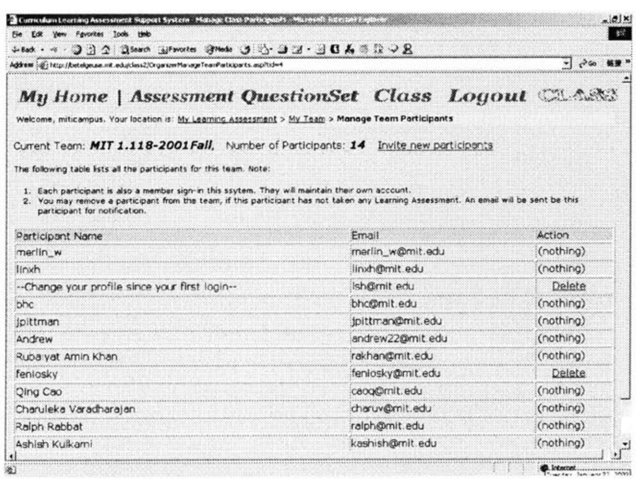


Figure 6-3: Member Management Center

Team/Member Management

- **Class/Team Management**
  - ➢ Create Class

- ➢ Modify Class
- ➢ Invite Class/Team Member
- ➢ Delete Class

- **Member Management**

  - ➢ Invite Team Member by Email
  - ➢ Delete Team Member
  - ➢ Modify Team Member Information
  - ➢ Set Invitation Method

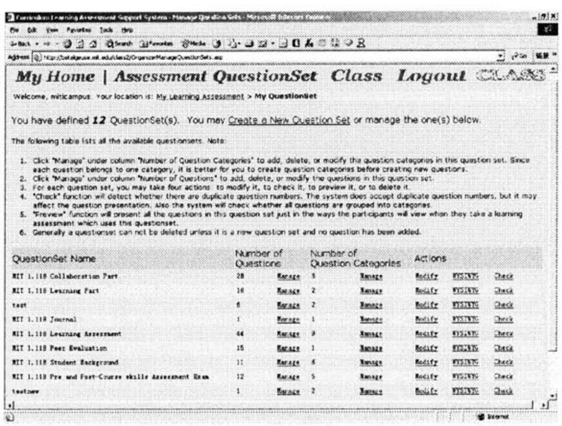


Figure 6-4: Question Set Management Center

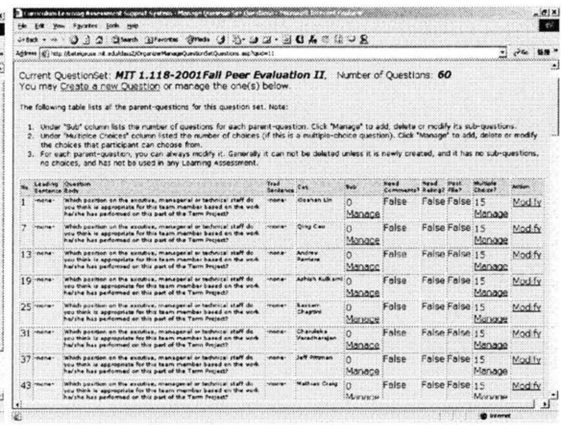


Figure 6-5: Question Management Center

Question Management

- **QuestionSet Management**

  - ➢ Create QuestionSet
  - ➢ Modify QuestionSet
  - ➢ Delete QuestionSet
  - ➢ Question Category Management (Sub System)
  - ➢ Question Management (Sub System)
  - ➢ WYSIWYG for each QuestionSet
  - ➢ Error Checking for QuestionSet

- **QuestionCategory Management**

  - ➢ Create Category
  - ➢ Modify Category
  - ➢ Delete Category

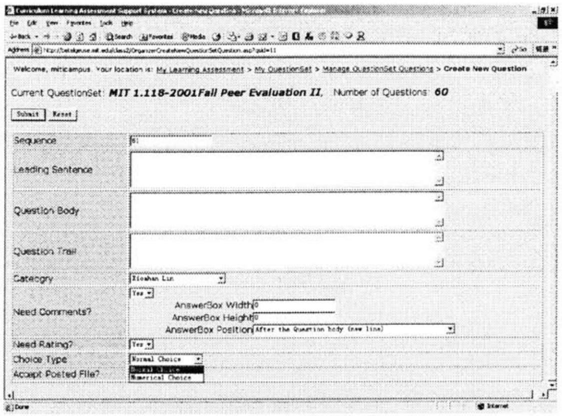


Figure 6-6: Question Creation Center

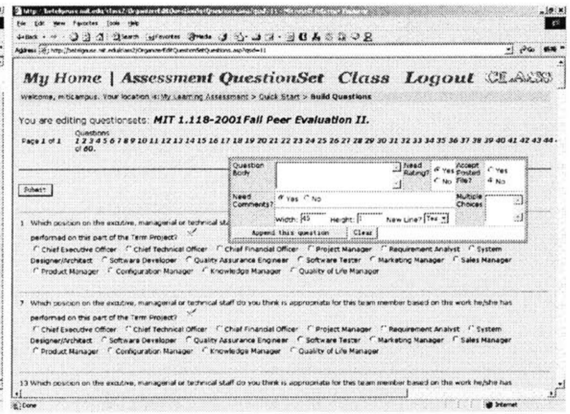


Figure 6-7: Question Preview and Check

- **Question Management**

  - ➢ Create Question: Question can be created online in abundant formats and styles, such as Single Choice Question, Multiple Choices Question, Numerical Choice Question, AnswerBar Question, AnswerBox Question, List Question, Rating Question, File Upload and etc.
  - ➢ Modify Question in WYSIWYG way
  - ➢ Delete Question
  - ➢ Sub Question Management (same as Question Management)
  - ➢ Multiple Choice Management (Sub System)

- **Multiple Choice Management**

  - ➢ Create Multiple Choice
  - ➢ Modify Multiple Choice
  - ➢ Delete Multiple Choice

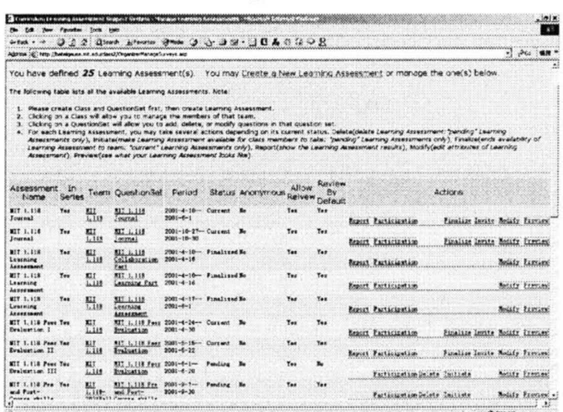


Figure 6-8: Assessment Management Center

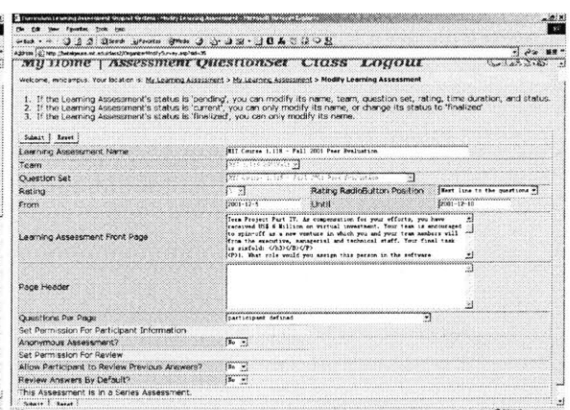


Figure 6-9: Assessment Creation Center

Assessment Management

- ➢ Create Assessment: for specified Team using specific Question Set

- ➢ Create Single Assessment or Series Assessment: by daily, weekly, monthly or any specific intervals automatically
- ➢ Adjust Assessment Control Properties: valid period, assessment status (pending, current, finalizing), participation anonymity, in series or not, access permission and privilege
- ➢ Modify Assessment
- ➢ Preview Assessment in WYSIWYG way
- ➢ Initialize Assessment
- ➢ Finalize Assessment
- ➢ Invite Class/Team for Assessment
- ➢ Invite Team Member for Assessment
- ➢ Generate Assessment Report (Report Management Sub System)
- ➢ Generate Participation Report (Participation Management Sub System)

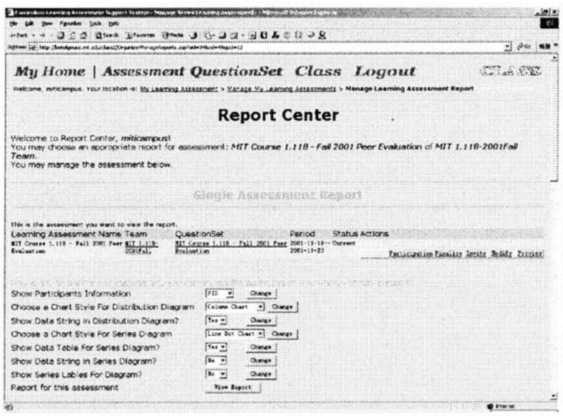


Figure 6-10: Assessment Report Center

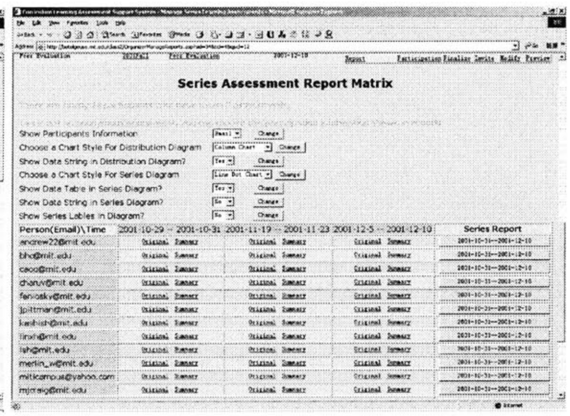


Figure 6-11: Series Assessment Report Matrix

Report Management

- ➢ Generate Report Matrixes: by different combinations of assessment space dimensions
- ➢ Generate Assessment Report in Report Matrix: such as Individual or Team Report in Single Assessment or in Series Assessment
- ➢ Statistical analysis (Frequency, Min, Max, Mean, Mode, Standard Deviation, Distribution and Behavior Change Over Time) for quantitative questions
- ➢ Generate Printable Diagrams for Statistic Report: Statistic Diagram, Distribution Diagram, Series Diagram and Legend Diagram in various chart styles (Bar Chart, Column Chart, Dot Graph, Line Graph and Dot-Line Graph): (Graph/Diagram Generation Sub System)
- ➢ Control Diagram Generation Properties (Chart Style, Color, Background, Data String Visibility and Data Table Visibility)
- ➢ Report Sorting, Indexing and Searching

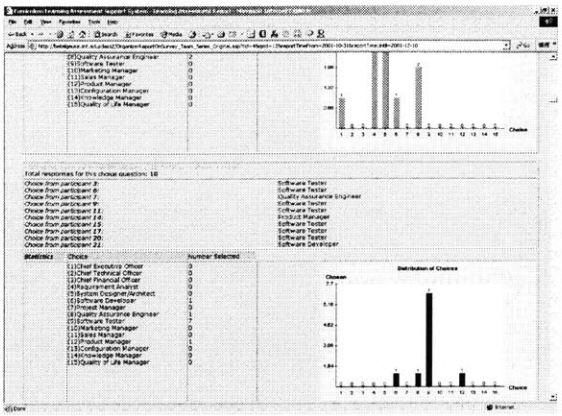


Figure 6-12: Assessment Choices Distribution

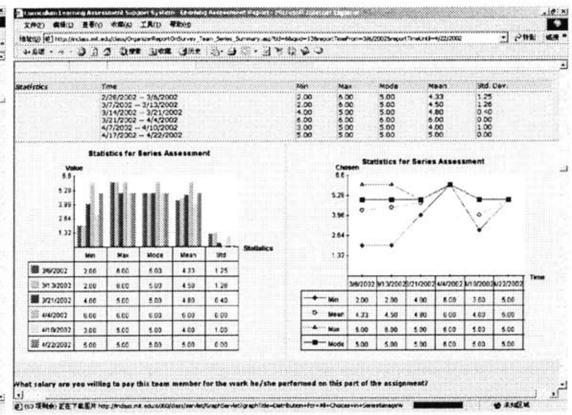


Figure 6-13: Series Assessment Longitudinal Statistic Report

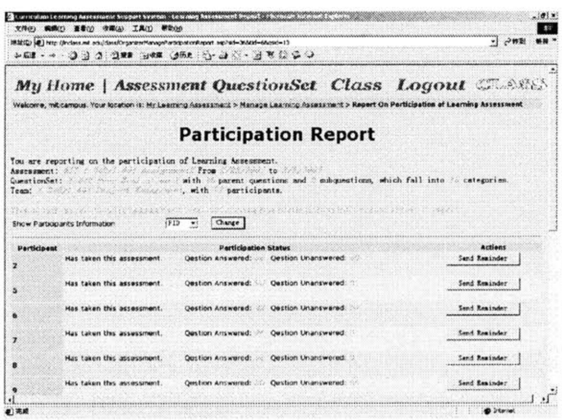


Figure 6-14: Participation Management Center

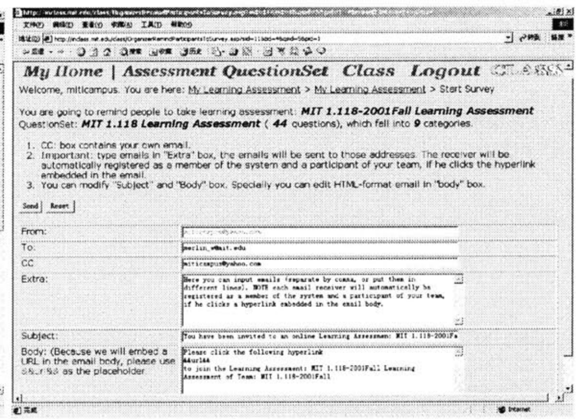
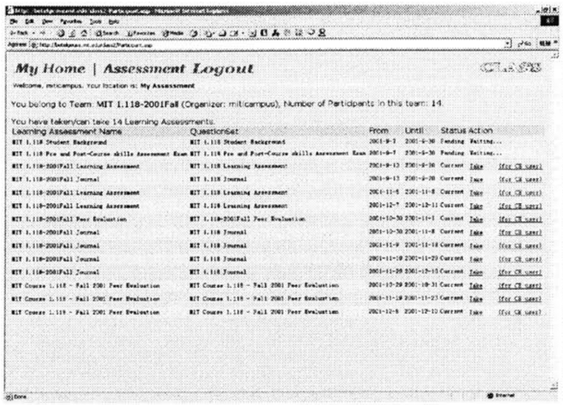


Figure 6-15: Send Reminder for Participation

Participation Management

- Generate Participation Report
- Monitor members' participation in current assessment
- Remind participants of the missing questions and incomplete answers in the assessment
- Generate notification and send reminder to participants

6.2.2 Participant Functionality



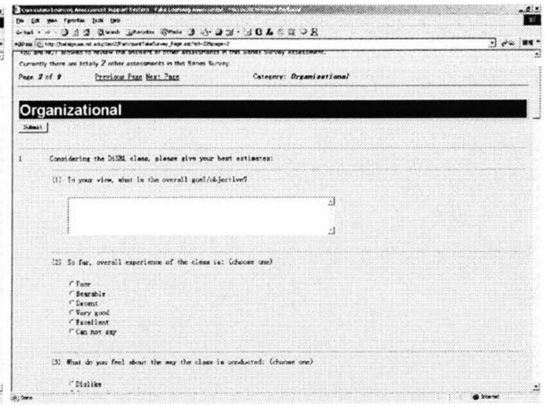


Figure 6-16: Participant's Assessment Management Center **Figure 6-17: Participant Take Assessment**

Account Management

- System Sign In (as an existing member)
- System Sign Up (as a new member)
- User Profile and Account Update
- Organizer Registration

Assessment Management

- Assigned Team Management
- Take Assessment
- Control Assessment Review Properties
- Submit Assessment
- System Logout

6.3 System Implementation and Technology

6.3.1 System Implementation Special Requirements

System Performance

- High Robustness
- High Concurrency
- High Reliability
- High Scalability

User Interface and Access

- Friendly user interface and easy to use
- Separate user interface with presentation for scalability and client device independent
- All management like Question Creation, Question Management, Assessment Management and Team/Member Management should be web-based and convenient
- Participants just use simple browsers to take assessments, such as traditional web browsers (Microsoft Internet Explorer 4.0 or Netscape 4.0) or mobile device browsers (Windows CE Internet Explorer for PDA and UP.Browser for Phone) in future

Question and Assessment Creation

- Question and assessment creation should be web-based
- Dynamic and flexible question and assessment creation
- Reuse questions from Question Bank to create new question set of an assessment

Question and Assessment Display

- Separate data structuring, data definition and data representation
- Content should be delivered in a flavor of HTML that both browsers can read and avoid of any browser specific tag extensions
- Different question formats and styles can be displayed in specified way, including Display Type (list box, combo box, radio buttons, check boxes or text area) and Layout (vertical or horizontal, position)
- Any changes to formatting and styles should be implemented easily

Report Generation and Display

- Generate assessment report and integrated diagrams both in display mode and in printable mode
- Dynamically generate charts and diagrams for different reporting purposes on fly in abundant formats
- Easily control the report generation properties
- Easily control the diagram formats and styles from the client side

6.3.2 System Implementation Technology

According the system implementation requirements and system architecture, the following standards and software technologies have been adopted as main supports while structuring CLASS system, to realize all the functionalities and increase system flexibility with relatively high performance.

- Multi-Tiered Thin-Client Application Server Architect (Browser/Application Server/DB Server)
- Server-Centric Solution with Client-Side Interaction
- DBMS (SQL Server)
- Microsoft ASP Programming Solution
- Scripting Language: VBScript, JavaScript
- J2EE Solution (Java Servlet, Java Server Page, Java Bean), Java, Java Applet, RMI

Web Application Server and Backend System

The Web Application Server is unlike a simple web server. Typically, a web server only provides information, usually static, generalized content, while the application server can generate dynamic content and information according to different user's request or customization, as well as interact with back-end legacy data centers and applications. Web Application Server is a high performance, multi-threaded, and multi-processing application server, which can handle a high number of concurrent requests, database connections, and sessions, and provides optimal performance even under heavy loads. Web Application Server offers:

- The highest performance and scalability, capable of scaling to millions of users. A high-performance application server environment, capable of delivering demanding business applications under peak loads
- New caching, multithreading and multiprocessing capabilities offer better performance than Web Server. An application can optimize performance by processing requests on multiple threads, which maximizes CPU resource utilization
- To improve performance, the Application Server caches database connections so that commonly used existing connections are re-used rather than re-established each time. Connection caching avoids the overhead involved in creating a new database connection for each request

- Proven reliability and transaction integrity, providing availability to customers on a 24x7 basis, and offering a solid platform for extending existing and new business-critical applications through the Web
- Support for distributed transactions, with two-phase commit technology. Additional systems resources can be added for improved availability with assured transaction throughput
- Additional standards-based data connectivity and integration, improving and extending connectivity to data stores
- Application Server supports state and session management capabilities required for Web-based applications. Application Server provides a number of classes and interfaces that can be used to maintain state and user session information
- Improved management and administration features
- Scalable and legacy integration, leveraging existing applications and data
- Enterprise management capabilities, including network management facilities that integrate into an enterprise management environment

In this research environment, Microsoft IIS (Internet Information Server) is used as main Web Application Server and Web Server to enforce most of the application logics and generate dynamic contents to support different clients, combining the technologies of ASP, VBScript/JavaScript, Java, Servlet, HTML, WML, XML and XSL. The server application opens connections to the DBMS (Database Management System), which is Microsoft SQL Server 2000. IIS can be running on the same server as SQL Server, or it can connect distributed SQL Server across network.

OLE DB, Microsoft's system-level data access interface to both relational data sources and non-relational data sources, exposes a collection of COM (Component Object Model) interfaces to system programming. In this system, OLE DB Provider for SQL Server is used to interact with SQL Server 2000. ADO (ActiveX Data Objects) is Microsoft's new high-level programming interface built on top of OLE DB Providers. ADO is used in ASP codes to open connection, retrieve record sets and manipulate data.

Another Web Application Server has been used is Apache Tomcat Server to support server side Java technologies, which may be running on the same server of IIS but monitoring the client requests from different port. Tomcat is the servlet container that is a free, open-source implementation of Java Servlet and JavaServer Pages technologies developed under the Jakarta project at the Apache Software Foundation. Tomcat Version **3.3** is the current production quality release for the Servlet 2.2 and JSP 1.1 specifications.

What each user needs is a standard web browser, like Internet Explorer and Netscape Navigator, or WML browser for WAP-enabled Phone and Pager to access the system. The browser will interpret and display ASP-generated HTML (HyperText Markup Language) or WML (Wireless Markup Language) pages on client devices, to enable users to fulfill all the common tasks involved in an assessment process.

ASP (VBScript and JavaScript)

Active Server Pages (ASP) technology provides a framework for building dynamic HTML pages that enable Internet and Intranet applications to be interactive. ASP's are implemented using server side scripting that can be performed in any language such as Visual Basic, Microsoft's JScript, Java or C. ASP allows interaction with ODBC compliant databases on the web server, such as; Microsoft Access, Microsoft SQL Server, Oracle, Informix, or Sybase. ActiveX controls can optionally be used to encapsulate functions on the client computer that interact with ASP on the server. Both Netscape Navigator and Microsoft Internet Explorer browsers as well as other browsers can view ASP pages because the ASP is executed on the server and delivered to the client computer as simple HTML. JavaScript is also a scripting language developed by Netscape Communications Corporation to permit more interactive HTML pages. JavaScript is primarily used as a client-side language, in that JavaScript programs are part of HTML pages, with the JavaScript code being executed by the browser. JavaScript can control the browser, opening new windows, writing input from one window to another and even close windows. JavaScript can also validate the users input in a form prior to it being submitted to a server side program. In the CLASS system ASP environment, VBScript are used to realize the main server-side functionalities, mixed with JavaScript to enhance the client-side interactive capabilities for users:

- Implement CLASS server components and realize all logics and functionality in server side
- Connect with databases to retrieve data for assessment and save results
- Control interaction protocols and assessment processes among server components and between client and server
- Generate dynamic and customized contents for client side from server
- Deliver assessments to web browser clients and gather results from distributed clients

- Improve client side interaction and input data validation

XML and XSL

Extensible Markup Language (XML) is a meta-markup language that provides a format for describing structured data and a markup language for documents containing structured information. Structured information contains both content (words, pictures, etc.) and some indication of what role that content plays (for example, content in a section heading has a different meaning from content in a footnote, which means something different than content in a figure caption or content in a database table, etc.). Almost all documents have some structure. A markup language is a mechanism to identify structures in a document. The XML specification defines a standard way to add markup to documents. This facilitates more precise declarations of content and more meaningful return results across multiple platforms. In addition, XML enables a new generation of Web-based data viewing and manipulation applications, with lossless exchange of complex data between systems that use different formats.

With XML as a base, it is fairly easy to reformat content using XSL, or eXtensible Stylesheet Language. Normally store the content in XML and use XSL to format the output as it is sent to the user client. The XSL transformation is done on the server side, and the client will never know that the content was stored in XML format and not in plain HTML, WML or any other format for that matter. So choosing XML and XSL to maintain the separation of the user interface from the structured data should be a good solution for flexibility of the CLASS system and for future WML support.

- **XML**
  - ➢ Question and assessment definition: create and define the data structure of questions in the assessment and the assessment information
  - ➢ Assessment results: define the data structure of the answers given to the questions in a assessment
  - ➢ Reporting: define the data structure of the summary of the answers given to an assessment report
- **XSL**
  - ➢ Convert question definition into specific format in defined transformation
  - ➢ Convert assessment definition into specific format in defined transformation

- ➢ Convert assessment results into report or reportable formats
- ➢ Convert question and assessment into different user interfaces, for HTML supported browser or WML supported browser

- **Visual Basic ActiveX In-Process Server (DLL)**
  - ➢ Encapsulate database access
  - ➢ Encapsulate conversion from RecordSet to XML
  - ➢ Deliver XML to ASP page for display

Due to the history of the system design and time constrains, XML solution has not been fully implemented in CLASS system, but only part of the data structures are defined using XML for flexibility.

J2EE platform

To realize a reliable, scalable and high performance solution for the distributed learning environment, varieties of Java technologies have been leveraged to implement part of the server components and backend system of CLASS, as well as to support the client side interactive programs, especially some functionalities need more complicated processing that cannot be handled by ASP. The Java™ 2 Platform, Enterprise Edition (J2EE™) technology provides a component-based approach to the design, development, assembly, and deployment of enterprise applications, which is a preferred platform for the solution. The J2EE platform offers a multi-tiered distributed application model, the ability to reuse components, integrated Extensible Markup Language (XML)-based data interchange, a unified security model, and flexible transaction control. In the multi-tiered distributed application model. Application logic is divided into components according to function, and the various application components that make up a J2EE application can be installed on different machines depending on the tier in the multi-tiered J2EE environment to which the application component belongs. Figure 6-2 shows two multi-tiered J2EE applications divided into the tiers conceptually described in the following list.

- Client-tier components run on the client machine
- Web-tier components run on the J2EE server
- Business-tier components run on the J2EE server
- Enterprise information system (EIS)-tier software runs on the EIS server

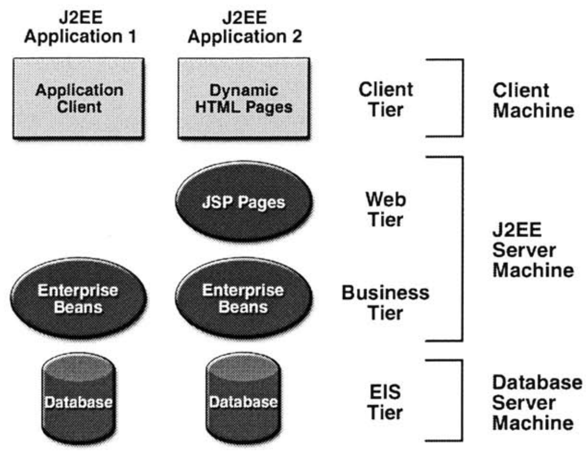


Figure 6-18: Multi-tiered J2EE applications (Sun)

J2EE applications are made up of components. A J2EE component is a self-contained functional software unit that is assembled into a J2EE application with its related classes and files and that communicates with other components. The main J2EE components and technologies have been used in the CLASS system are:

- Application clients and applets are components that run on the client.
- Java Servlet and JavaServer Pages ™ (JSP ™) technology components are Web components that run on the server.
- Enterprise JavaBeans™ (EJB™) components (java beans) are business components that run on the server.

J2EE Clients

A J2EE client can be a Web client or an application client.

Web Clients - A Web client is sometimes called a *thin client.* A Web client consists of two parts: dynamic Web pages containing various types of markup language (HTML, XML, and so on), which are generated by Web components running in the Web tier, and a Web browser, which renders the pages received from the server.

Applets - A Web page received from the Web tier can include an embedded applet. An applet is a small client application written in the Java programming language that executes in the Java virtual machine installed in the Web browser. However, client systems will likely need the Java Plug-in and possibly a security policy file in order for the applet to successfully execute in the

Web browser. The applets are used in CLASS system as interactive simulation tools for the students in collaborative learning.

JavaBeans™ Component Architecture

The server and client tiers might also include components based on the JavaBeans component architecture (JavaBeans component) to manage the data flow between an applet client or Web Client and components running on the J2EE server or between server components and a database. JavaBeans components are not considered J2EE components by the J2EE specification.

JavaBeans components have instance variables and `get` and `set` methods for accessing the data in the instance variables. JavaBeans components used in this way are typically simple in design and implementation, but should conform to the naming and design conventions outlined in the JavaBeans component architecture.

J2EE Server Communications

Figure 6-3 shows the various elements that can make up the client tier. The client communicates with the business tier running on the J2EE server either directly or, as in the case of a client running in a browser, by going through JSP pages or servlets running in the Web tier.

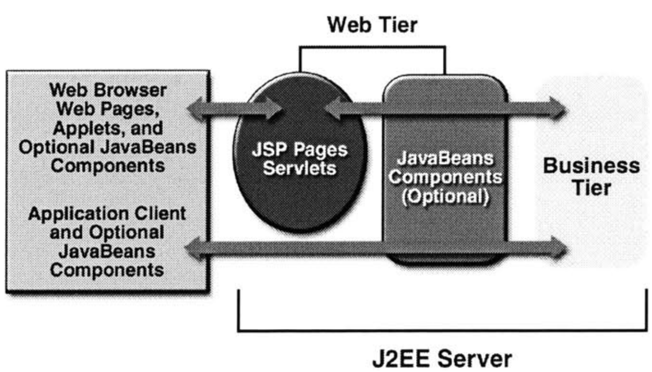


Figure 6-19: J2EE Server Communications and Web Components (Sun)

Web Components

J2EE Web components can be either servlets or JSP pages. *Servlets* are Java programming language classes that dynamically process requests and construct responses. *JSP pages* are text-based documents that execute as servlets but allow a more natural approach to creating static content.

Static HTML pages and applets are bundled with Web components during application assembly, but are not considered Web components by the J2EE specification. Server-side utility classes can also be bundled with Web components and, like HTML pages, are not considered Web components.

Like the client tier and as shown in Figure 6-3, the Web tier might include a JavaBeans component to manage the user input and send that input to java beans running in the business tier for processing.

ASP with J2EE Solution

As ASP solution and J2EE solution have each advantage, they are combined together for the CLASS system implementation. Most of the server side components and client side user interface are built using ASP with scripting solution, which are running in IIS environment, such as Interaction Management Server, Team/Member Management Server, Question Management Server, Assessment Management Server, Participation Management Server, and part of Report/Analysis Management Server. Whereas, some complicated functionalities need special Java classes support and J2EE capabilities that cannot be achieved by ASP solutions, they are fulfilled using various J2EE technologies, which are running in Tomcat Application Server and JVM. For example, Graph/Diagram Generation Server uses J2EE and a special Image Encoder class to generate various printable diagrams as Java Servlet graphs dynamically, which are embedded into ASP pages for the assessment reports. To track students' interaction with simulation tools in CLASS system, Interactive Simulation Management Server needs to communicate with distributed simulation applets in the collaborative learning environment for dispersed students, and provides server-side services to collect data and regenerate the interaction process of each student. Thus, Java RMI technologies are used to realize distributed computing services and collaborate with other services provided by server components in ASP environment. IIS and Tomcat Application Server are working together in CLASS system to integrate ASP and Java working environment, which control the communications between client and server, and interactions between server components through different monitoring port.

6.4 System Evaluation and Comparison

In the education domain, few instruments are available to measure collaborative learning and interaction effectiveness and help to adjust dimensions relevant to collaborative learning such as teaching practices, student attitudes and behavior, or peer support. Although there are several Web Survey or Assessment systems and solutions existing nowadays in the web survey and assessment market, most of them are created for business market research, like customer preferences and satisfaction feedback, and some of them are focusing the learning tests and quizzes and all of them are commercialized in the market. To evaluate CLASS system, several solutions have been chosen to compare with CLASS system in Table 6-2 from methodology support, system implementation technology, main assessment processes and major functionalities that are required to support an effective collaborative learning assessment. The four solutions that have been chosen are:

Questionmark Perception (Question Mark Computing Ltd.) – A software package helps users to create and deliver tests, quizzes and surveys on Intranets, the Internet or using Windows PCs. It has assessment-authoring tool for both online web client and Windows PCs, instant feedback to participants at item, topic and/or assessment levels, and online viewing of results, reports and item analysis. This solution provides abundant features to create and control the questions, to customize assessment and report styles, and has focus on the educational environment.

SurveySolutions for the Web (Hoare Research Software Ltd.) – A solution to create professional surveys quickly, post them in website or distribute them via email, collect responses automatically, analyze results and produce effective and stylish presentations instantly. The solution uses an intuitive word processor interface for questionnaire design and provides advanced functionality for market research.

WebSurveyor 2.0 (WebSurveyor Corporation) – An online survey software and hosting solution to offer the tools that need to create, publish, announce and analyze results from online surveys. It can control some aspect of each survey's appearance, results and respondent list. WebSurveyor uses desktop software to create, publish surveys to user's account on the survey hosting service and also uses the software to gather and analyze results.

Zoomerang (MarketTools, Inc.) - It is an entirely Web-based product; no software is installed locally. Each survey is deployed on the company's Web site, and an e-mail message with the survey's URL is sent to the target audience. It's easy to use but has limited functionality. It has some pre-built surveys in four categories: Business, Community, Personal/Social, and Education, which can be edited for new surveys.

Table 6-2: Assessment System Evaluation and Comparison

Category	Features	CLASS	Question Mark	Survey Solutions	WebSurveyor 2.0	Zoomerang
Methodology Support	Pedagogical Theory Support	High	Moderate	N/A	N/A	Moderate

	Collaborative Learning and Distributed Learning Support	High	N/A	N/A	N/A	N/A
	Multi-dimensional Assessment Model	High	Moderate	N/A	N/A	N/A
	Assessment Space and Matrix	High	N/A	N/A	N/A	N/A
Server Deployment	Server Language	HTML, ASP, Java, J2EE (Servlet, JSP, Java Bean) Applet, RMI	HTML, CGI	HTML, Perl	N/A	HTML, ASP
User Management and Control	Team/Member Management	High	Low	Low	Low	Low
	Individual Customized Working Space	High	N/A	N/A	N/A	N/A
	Multi-Team Multi-Assessment Control	High	N/A	N/A	N/A	N/A
	Role Privilege Control (Organizer and Participant)	High	N/A	N/A	N/A	N/A
	Embedded e-mail Invitation and Notification	High	High	N/A	High	High
Question and Assessment Generation	Authoring Tools	Web-Based	Locally/Web-Based	Locally in PC	Locally in PC	Web-Based
	WYSIWYG Capability	High	Moderate	N/A	N/A	N/A
	Multiple Question Format/Style Support	Moderate	Low (Web) High (Window)	Moderate	Moderate	Low
	Question /Question Set Reusability	Moderate	Moderate	Low	High	Low
	Question Sequence Flexibility	Moderate	Moderate	Low	N/A	Moderate
	Question and Category Combination	High	Moderate	Low	N/A	High

	Image, Audio, Video, Applet Support	Moderate	Moderate	Low	Moderate	Moderate
Question and Assessment Display	Single or Multiple Page Assessment Interactive Format	High	N/A	High	High	N/A
	Control of Number of Questions in One Page	High	N/A	N/A	N/A	Moderate
	Customized Question Position	Moderate	Moderate	Low	N/A	High
	Customized Assessment Style	Moderate	Low	Moderate	Low	High
	Look and Feel Control	Moderate	Moderate	Moderate	N/A	Moderate
Assessment Taking	Security Check and User Validation	High	High	Low	Low	Low
	Assessment Initialization, Invitation and Finalization	High	Moderate	Low	Low	Low
	Assessment Validation and Access Period Control	High	High	Low	Low	Low
	Question/Page Skip and Return	High	Moderate	High	High	N/A
	Intelligent Assessment (Skip and Branches)	N/A	Moderate	Moderate	High	N/A
	Missing Answer Check	High	High	N/A	N/A	N/A
	Submission Summary	High	High	N/A	N/A	N/A
	File Management	High	N/A	N/A	N/A	N/A
	Anonymity Control	High	N/A	N/A	N/A	N/A
	Review Answers in Series Control	High	N/A	N/A	N/A	N/A
Data Collection	Data Validation	High	Moderate	Low	Low	Moderate

	Variable Range and Type Checking	Moderate	Moderate	Low	Low	Low
	Server Side/Local Data Storage	Server	Server/Local	Server	Server/Local	Server
Reporting and Analysis	Participation Monitoring, Reporting and Notification	High	N/A	N/A	N/A	N/A
	Anonymity Control	High	N/A	N/A	N/A	N/A
	Statistic Report: Min, Max, Mean, Mode, Standard Deviation, Variance	High	High	Moderate	Moderate	N/A
	Distribution, Frequency	High	High	N/A	Moderate	Moderate
	Qualitative Report	High	High	High	High	High
	Report Matrix (by Person and Time Axial)	High	N/A	N/A	N/A	N/A
	Individual and Team Report	High	High	Moderate (Individual)	Low	Low
	Single Assessment Report	High	High	Moderate		Low
	Series Assessment Report	High	N/A	N/A	N/A	N/A
	Bar/Column Chart (Distribution, Frequency Chart, Statistic Chart, Series Chart)	High	Moderate	High	Low	N/A
	Dot/Line Diagram (Distribution Diagram, Statistic Chart, Series Diagram, Legend Diagram)	High	N/A	Moderate	Low	N/A
	Report Printing Control	Moderate	Moderate	N/A	N/A	N/A

	Report Sorting and Searching	High	Moderate	N/A	N/A	N/A
Online Chart and Diagram	Generate on Fly (Image/Applet)	High	Moderate	Moderate	Low	Low
	Image Printing Support	High	Moderate	Moderate	Low	N/A
	Title, Label, Legend, Data String Customization	High	N/A	N/A	N/A	N/A
	Data Table in Diagram Control	High	N/A	N/A	N/A	N/A
	Diagram Type Control	High	N/A	N/A	N/A	N/A
Interactive Simulation Track Engine (Implementing)	Distributed Simulation Tools Control (Applet, Flash)	High	N/A	N/A	N/A	N/A
	Remote Service Access	High	N/A	N/A	N/A	N/A
	Uniform Data Interface	High	N/A	N/A	N/A	N/A
	Interaction Representation	High	N/A	N/A	N/A	N/A
	User Behavior Tracer	High	N/A	N/A	N/A	N/A
	Progress Report (Individual/Team)	High	N/A	N/A	N/A	N/A
Others	Help, tutorials, and tips	Moderate	High	Moderate	Moderate	Moderate
	Installation and setup	Moderate	Moderate	Low	Moderate	High
	Ease of Use and Navigations	Moderate	Moderate	Low	High	Moderate

Although each solution has its specialty, based on the comparison for the assessment and survey systems in the industry, CLASS system has the following major differentiation and advantages for collaborative learning assessment:

- Pedagogical framework and educational theories support for learning and assessment
- Distributed learning and collaborative learning environment support

- Embedded multi-dimensional assessment model and comprehensive assessment space and matrixes realization
- Pure web-based thin client system in high performance multi-tiered Application Server architecture
- Both textual and graphical based assessment and interactive simulation based assessment support
- Completed collaborative learning assessment process and functionality implementation
- Flexible question and assessment creation and presentation
- Considerate various question and assessment properties control
- Effective Team /Participant management for collaborative learning environment and assessment participation monitoring and control
- Dynamic multi-dimensional assessment data analysis and report generation
- Easy assessment access and simple taking process for distributed learning team members

Meanwhile, some insufficient points have also been revealed for future CLASS system improvement:

- More friendly user interface and easy navigation
- More flexible question model, considering the question types, question styles, question reusability and question relocation
- More effective assessment control, considering assessment branching and question sequence randomization
- More flexible data exchange and sufficient statistical analysis, considering the online assessment data import and export, external analysis system interface, more complicated statistical analysis and even online data mining

Chapter 7 System Test and Case Study

7.1 Background and Test Environment

Based on the pedagogical framework and Distributed Collaborative Learning and Assessment Framework, a prototype of Virtual Collaborative Learning Environment and Collaborative Learning Assessment Support System (CLASS) have been developed to demonstrate basic functionality of the virtual learning assessment space to improve collaborative learning effectiveness and team health. This system been tested and used for teaching and collaborative learning practices in MIT Distributed Systems Engineering Lab (DiSEL) course 1.118 - Distributed Development of Engineering Information Systems and MIT course 1.040/1.401 – Project Management, led by the Intelligent Engineering Systems Laboratory (IESL) at MIT.

The Distributed System Engineering Lab (DiSEL) at MIT is an experimental practicum designed to prepare graduate engineering students for "real world" development experience in an academic setting. DiSEL was created to help students learn about the development life cycle of systems while designing and developing a marketable, innovative, and reliable product in a distributed setting. Recognizing the need to prepare students to be active participants in industry without too much re-training from companies, the DiSEL instructors designed their course to better prepare participants for their transition from "software engineering student" to "software engineering professional." Assessments of student learning, interactions and motivations in this setting provide insight into the efficacy of this collaborative environment as well as valuable lessons for comparable endeavors. To assure that this type of laboratory setting does in fact help students gain real world experience, and supports them throughout the learning process, the DiSEL Lab integrates educational frameworks and theories that support collaborative, distributed (distant), and project-based learning. The course described here is an initial stepping stone for a larger effort, led by the Intelligent Engineering Systems Laboratory (IESL) at MIT. The objectives of IESL are three-fold: (1) Study major challenges in the engineering industry; (2) conceptualize solutions to those challenges; and (3) use information technology to implement those solutions with the support of organizational change and process redefinition.

The semester-long project students are required to complete in the DiSEL Lab is the building of a synchronous collaboration and real-time application interaction system in the distributed computing environment to support multiple devices. Through this project, students learn about new communication technologies, develop entrepreneurial and collaboration skills, and create a collective memory repository for such an environment. By the end of the class, students should have developed a working version of the system efficiently and on time according to a schedule they set for themselves within the constraints of an academic semester. These challenges provide class participants with a "real world" experience in collaborative learning and working with different project teams, organizing their work and team to accomplish tasks, improving system development skills with project management, collaboration, and learning skills that may at first seem near impossible. Such efforts are critical for the type of innovative engineers the future demands.

7.2 Educational Setting for DiSEL Collaborative Learning

7.2.1 Pedagogical Framework

However, there is a critical difference between an industrial environment and a comparable educational setting: in classrooms special considerations need to be made for guiding students through their work at a level-appropriate pace, assessing student performances based on their level of understanding, and supporting student reflection. This shaping of students' experience therefore requires more of a planned and controlled setting than a real world, unpredictable development situation allows. To compensate for this discrepancy, to ease this process and to assure student understanding of the learning objectives, the DiSEL Lab incorporates a combination of pedagogical theories that support the diverse requirements of the course. With the aid of the Collaborative Learning Pedagogical Framework identified in Chapter 2, the instructors were able to articulate and prioritize their teaching goals, as well as students' expected performance. So the curriculum was cohesive and focused even though the project was ill defined.

7.2.2 Generative Topics and Throughlines

To keep students motivated and guide them through the collaborative learning activities in which they thoughtfully explore and construct new knowledge, DiSEL instructors needed to develop a flexible course schedule and allow for variable grade requirements

The DiSEL Lab is continuously changing and its Throughlines (See Chapter 2) are slowly evolving based on the five Generative Topics of the class: The System Development Life Cycle, Collaboration, Collective Memory, Technology, and Entrepreneurship. Five Throughlines emerged in association with the Generative Topics (See Chapter 2) of the class:

1. (System Development) In what ways are the roles of the project manager, requirements analyst, designer, programmer, knowledge manager, quality assurance specialist, tester and configuration manager interdependent and how do they support the system development process?
2. (Collaboration) In what ways can you collaborate and determine if your collaborations with colleagues were successful or unsuccessful?
3. (Collective Memory) How can others best understand your work and the decisions you have made throughout the project?
4. (Technology) How can you use currently available technology and push it in new directions?
5. (Entrepreneurship) How can an idea be developed and marketed?

These Throughlines help guide the inquiry and work of the students throughout the DiSEL course so that the knowledge gained in the class connects to a bigger picture that provides an integrated view of the subject matter.

7.2.3 Performances of Understanding

According the Pedagogical Framework, how students are expected to demonstrate their understanding should be outlined for them by the instructor(s) in the TFU worksheet under "Performances of Understanding." These are the activities students participate in that require them to demonstrate their collaborative learning of the Understanding Goals. Once these performances are clearly explained, assessing student work becomes more straightforward as students can discern for themselves whether they are generally meeting the performance criteria or not. To do this in the DiSEL course, the instructors created an Expectations Rubric (See Appendix 1) and handed it out within the first week of class. The Expectations Rubric clearly defined for students what was expected of their work throughout the course by identifying the learning categories the instructors planned to address, articulating the Understanding Goals, explaining the expected Performances of Understanding, and specifying the methods of Ongoing Assessment. This rubric was critical in the DiSEL implementation as it provided students with a type of job description such that they would receive in a real working environment and the role they should play in the collaborative learning process. These roles include: Chief Executive Officer, Chief Technical Officer, Chief Financial Officer, Project Manager, Requirement Analyst, System Designer/Architect, Software Developer, Quality Assurance Engineer, Software Tester, Marketing Manager, Sales Manager, Product Manager, Configuration Manager, Knowledge Manager and Quality of Life. To monitor and improve the collaborative learning effectiveness, meetings, journals, interviews, and various assessments of class participants have been designed and conducted to evaluate the through the whole collaborative learning process.

7.2.4 Course Instruments

The course has been organized around the three course organizational constructs, the lecture, the lab and the assignments.

Lectures – the instructor covers the theoretical basis for the understanding of the different roles of the software development process.

Lab – the students interacts amongst themselves to work on the assignments or the projects that they have been assigned to do. It induces collaboration and interaction among team members through the collaborative learning and they need to be able to be familiar with each other and build up trust within the team, which would serve as the basis for a better working relationship and success for the group term project.

Assignment – at the end of a lecture, there are an assignment on the relevant software development process role, which would be done by small groups of students.

Suggested readings – instructional material about each role, case studies and relevant standards should be made available to the students.

The lectures impart the theoretical knowledge. The suggested readings cover case studies and theoretical instructional matter, which covers the software development process role in more detail. The assignments help students get a better understanding of the course. The labs allow and also induce discussion of concepts about software development roles, which help the students clarify their doubts. Thus, every student gets a pretty good understanding about each software development process and responsibility of each role.

7.3 Collaborative Learning Process

The course includes both the design and implementation of a team-based real-time collaboration system project. The students will work on a software development plan through the development cycle, which covers project management, requirements analysis, system architecture and design, quality control, programming, configuration management, and testing. There are approximately fifteen roles within the software development process with which students will become familiar. For the final project of the course, students will assume different roles related to the core competencies involved in software development.

This course involves project-based collaborative learning environments and research laboratories that are designed to produce a marketable product. The objectives of knowledge and skills learning are achieved not only from individual learning but also from the cooperation and collaborative learning between the team members. The students draw on this experimental nature of the course to develop a practical and deeper understanding of the advantages and limitations of collaboration. This combination of tools and experiences will allow the students to experience the latest in collaborative design, most likely to be extensively used in the near future in all areas of engineering.

The collaborative learning takes place both in the physical and virtual environment. The Virtual Collaborative Learning Environment provides a distributed interaction space, virtual collaboration space and collaborative learning assessment space for the team members outside classroom and lab that support all the learning and interaction processes, synchronous and asynchronous communication as well as memory collection for the team projects. The students use the online virtual collaboration environment to share information, throw and catch problems, discuss issues, make suggestions and comments for problems, access schedule, lectures and suggested readings, download data and submit solutions, communicate with peers or instructors conveniently and effectively throughout collaborative learning process.

7.4 MIT 1.118 Collaborative Learning Assessment

To achieve the goal of education in this course, a set of learning assessments has been created in defined assessment space and carried out in the DiSEL course teaching and learning process using CLASS system. Each type of assessment has some specific objectives for different perspectives of collaborative learning.

MIT 1.118 Student Background – Collect information about students' demographic background, education background, culture background, work background, technical skills, expertise background and their reasons for taking courses. With the information, the instructor and students can fully acknowledge of the collaborative learning circumstances. Moreover, it will help the instructor to allocate resources effectively and divide groups for project more deliberately with consideration of diversity, and find out solutions to overcome geographical, cultural and temporal barriers.

MIT 1.118 Pre-Course Skills Assessment – Test the students' knowledge and skills related to the course objective and collaboration before the starting, which includes student knowledge about software development, about collaboration and organizational strategies, about entrepreneurship, suggestion about collective memory and use of technology. Based on the information, instructor can identify the class overall level of understanding to the learning objective and target knowledge, and make adjustment to the current course setting and schedule to best fit the participants.

MIT 1.118 Post-Course Skills Assessment - Test the students' understanding of knowledge and skills about learning targets acquired through the collaborative learning in the course. This assessment provides the evaluation of individual and team learning performance and effectiveness after the learning process.

MIT 1.118 Learning Journal - Each student will be required to keep a Journal/Design Notebook for this course. The journals need to be turned in every week through the online CLASS system. It helps students to reflect on their collaborative interactions with each other, their understanding of knowledge, comments and suggestions for the course and team. The personal and professional insights from students should prove valuable for the improvement of the class. In addition, this reflective or meta-cognitive process should help the students in deep thinking and future collaborative work endeavors. Moreover, from the professor and researchers' perspective the qualitative information give insight into the individual thinking and how the class is really progressing.

MIT 1.118 Integrated Learning Assessment – In different phases of the learning and working process, the students take the integrated assessment with comprehensive quantitative and qualitative questions about the knowledge, learning, collaboration, organizational process and infrastructure or recording of individual learning process. It integrates Self Assessment, Leader Assessment and Facilitator Assessment as a whole. In integrated assessment, most target questions and effectiveness variables can be formulated in quantitative way or need to be analyzed quantitatively. Integrated assessments given throughout the semesters can be useful for tracking learning behavior and progress of students, attitude towards the class and suggestions to improve the class. It is necessary that these surveys be so timed that they give adequate time to remodel course structure if so desired. Additionally, the assessment involves questions, which provide feedback to the instructors on the suggested recommendations. Care should be taken to eliminate biases. Assessment results give information about the effectiveness of the proposed recommendations and they may be duly modified or changed if the need arises. From the feedback of the assessment, students can have knowledge about their own understanding process and learning progress, and can avoid repeating mistakes by identify the common obstacles for understanding. Instructors can also use the data to monitor and analyze students' learning behavior and get individual results and cumulative team results for performance evaluation, and evaluate target effectiveness variables to find out the barriers to collaborative learning that need to be overcome.

MIT 1.118 Peer Assessment – Evaluate their peers in the same learning (sub) team or project (sub) team based on their perceived behavior, performance and contribution to each other and the team during the teamwork, interactions and collaborations of learning. The results of the peer assessment are used as one of the metrics for evaluation and grading for individual and team, based on the performance and competency. From the feedback of Peer Assessment, instructors can also monitor the relationship between team members and team health, solve conflicts, identify barriers to effectiveness and adjust team dynamics (team structure, responsibilities, workload, member roles, etc.) to improve the effectiveness of team collaborative learning. The performance evaluation is based on each person's role defined in DiSEL Expectations Rubric and each person may work as different role in different sub team for a series of assigned projects.

Most of these assessments implemented in CLASS system for DiSEL course are designed as Series Assessment over time, which can provide more valuable information about changes and progresses in longitudinal report through the learning process.

7.5 Learning Assessment Results

After collecting the data from distributed team members through CLASS system, the system carries out statistical analysis from different perspective and generates useful assessment report matrixes for the instructor that consist of various assessment reports. From these results of assessment reports, the instructor can identify the individual or team learning behavior, monitor the individual or team learning progress, analyze the team structure and process, evaluate the infrastructure and facilitators of the class, and observe the interaction and collaboration between members during learning for overall learning effectiveness improvement purpose.

The following sections give some sample questions and results of different collaborative assessments used to test CLASS system and reflect different aspects of collaborative learning in MIT course 1.118.

7.5.1 Individual Learning

Individual overall objective of the project is: (choose one)

(1)Very ambiguous (2)Clear, but needs better definition (3)Adequate (4)Very clear (5)Can not say

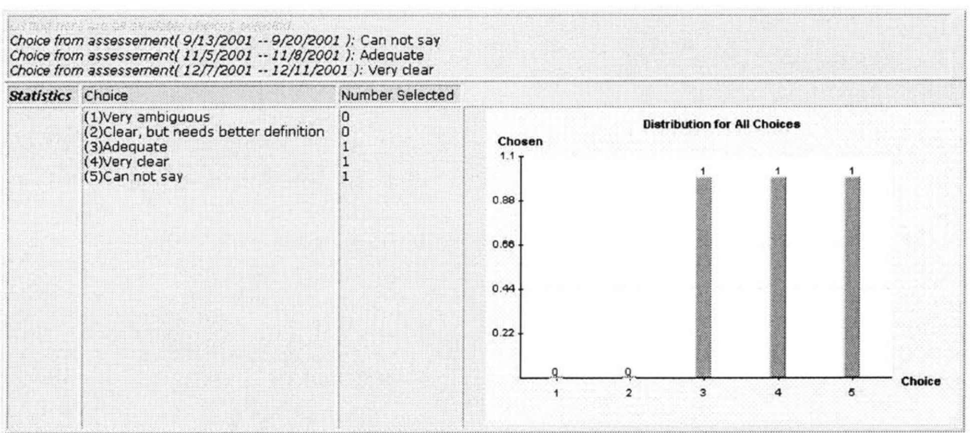


Figure 7-1: Individual Learning Objective Over Time

How would you rate your learning this month of the following skills?

(1) SOFTWARE DEVELOPMENT: How to develop a high quality software system? (Please rank, 1 = poor, 5 = excellent)

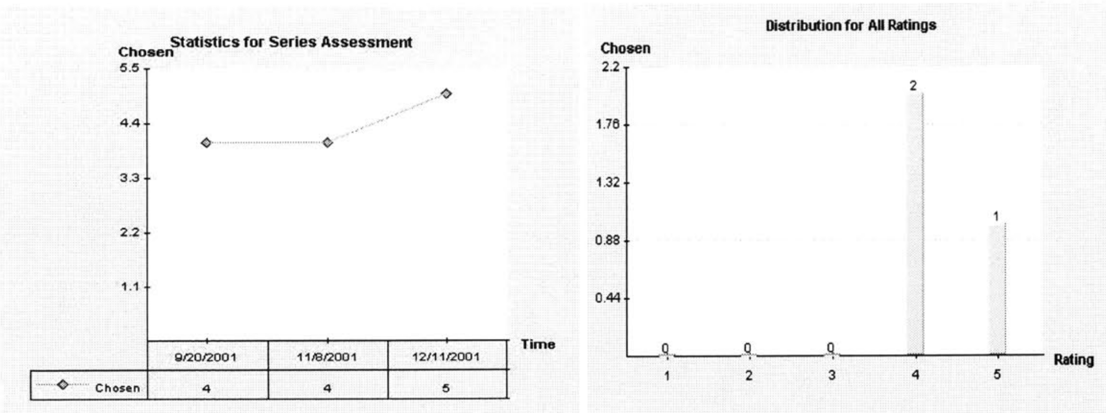


Figure 7-2: Software Development Skill Progress

(2) COLLECTIVE MEMORY: How to document and store your work so that team members can utilize your contribution to the project? (Please rank, 1 = poor, 5 = excellent)

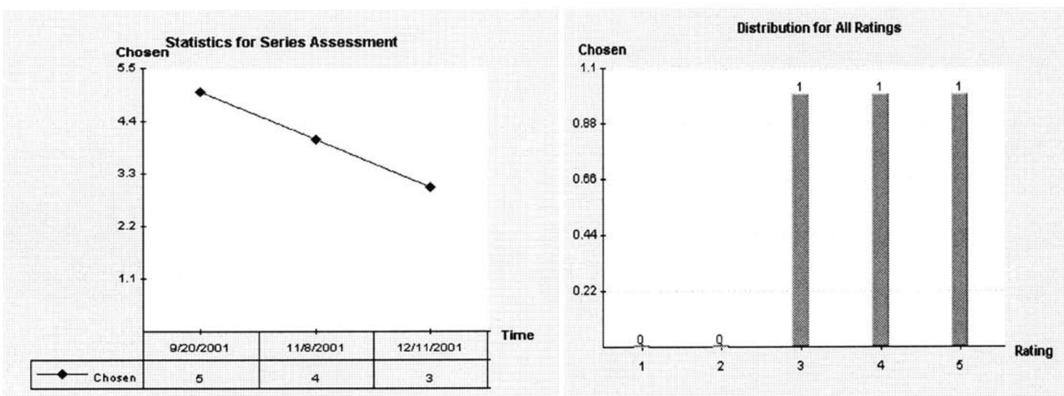


Figure 7-3: Contribution of Individual Collective Memory

(3) COLLABORATION: How to collaborate with team members when developing a product (please rank, 1 = poor, 5 = excellent)

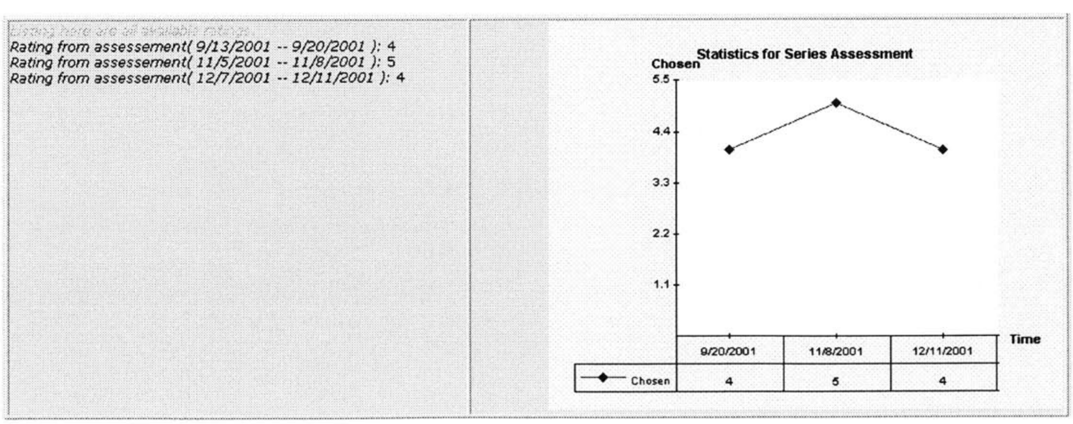


Figure 7-4: Individual Collaborative Learning

(4) Do you feel better prepared to solve communication and managerial problems in large teams after the work you have done in this Lab so far? (Please rank, 1 = ill-prepared, 5 = well prepared)

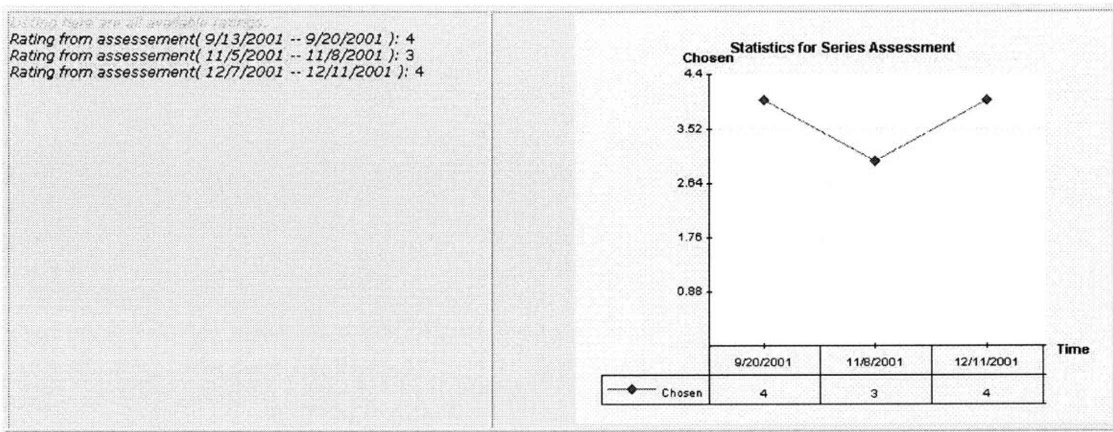


Figure 7-5: Communication and Management Skills Improvement in Large Teamwork

7.5.2 Course Settings and Instruments

Please rank the following instructional sources (#1 - most important, #2 - second in importance, #3- less important and so on) based on their contributions to the success of your monthly learning experience on a scale of 1 to 5.

(1) Lectures of Professor

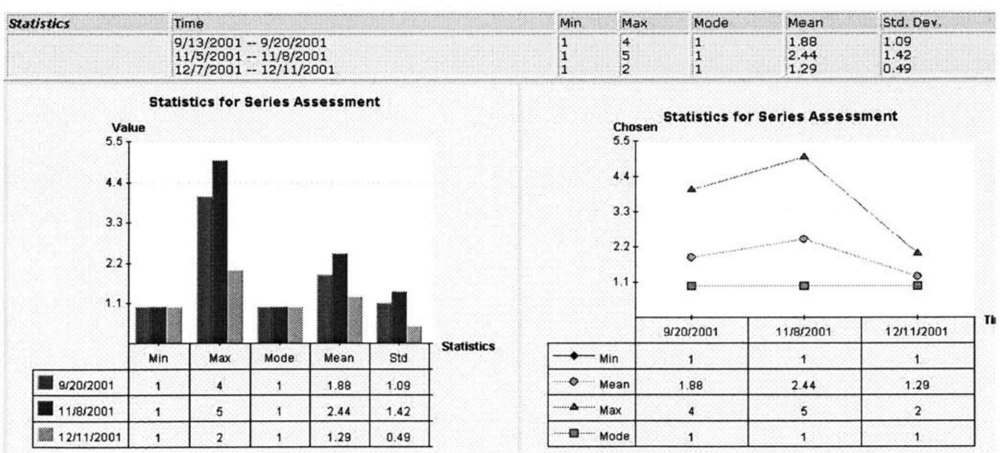


Figure 7-6: Effectiveness of Lectures

(2) Reading Assignments

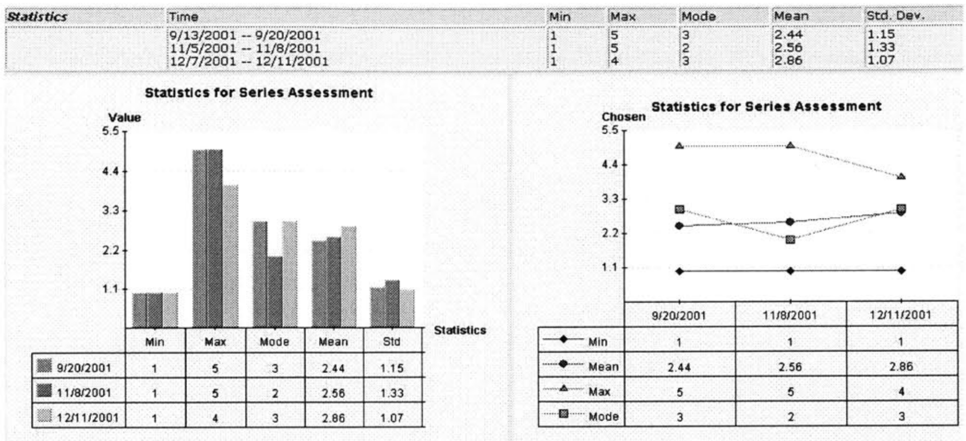


Figure 7-7: Effectiveness of Assignments

(3) Laboratories

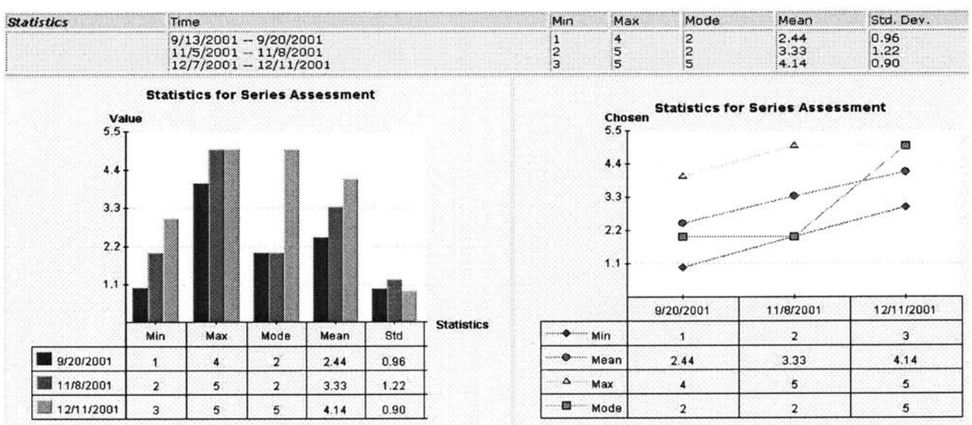


Figure 7-8: Effectiveness of Laboratories

(4) Teaching Assistant

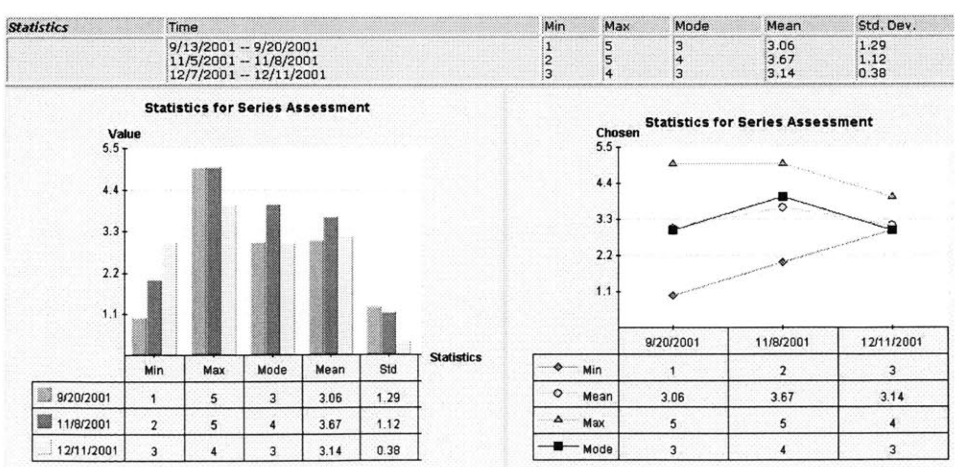


Figure 7-9: Effectiveness of Teaching Assistant

Have the reading assignments helped clarify the content of the lectures? (Please rank, 1 = a little, 5 = a lot)

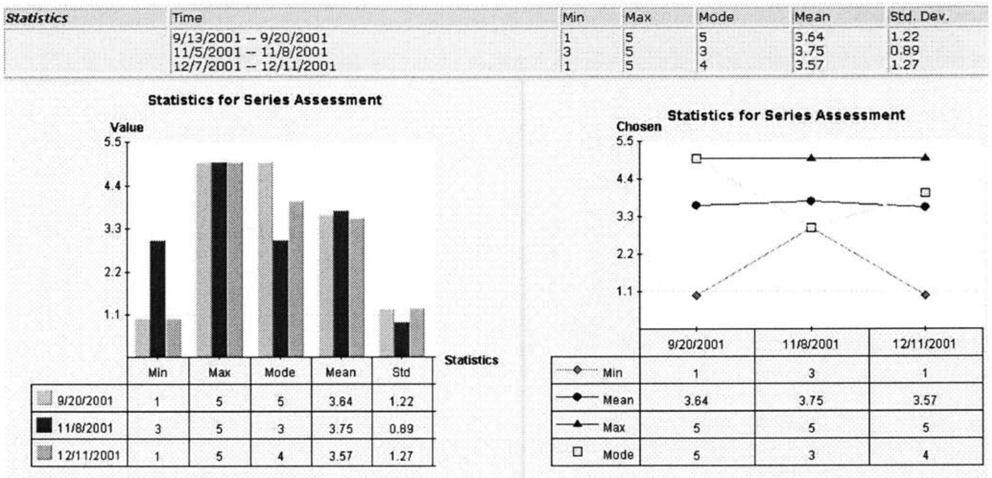


Figure 7-10: Reading Assignment Effectiveness for Lecture Content Clarification

7.5.3 Instructor Teaching

How well are the professors supporting you in your work on the project? (Please rank, 1 = a little, 5 = a lot)

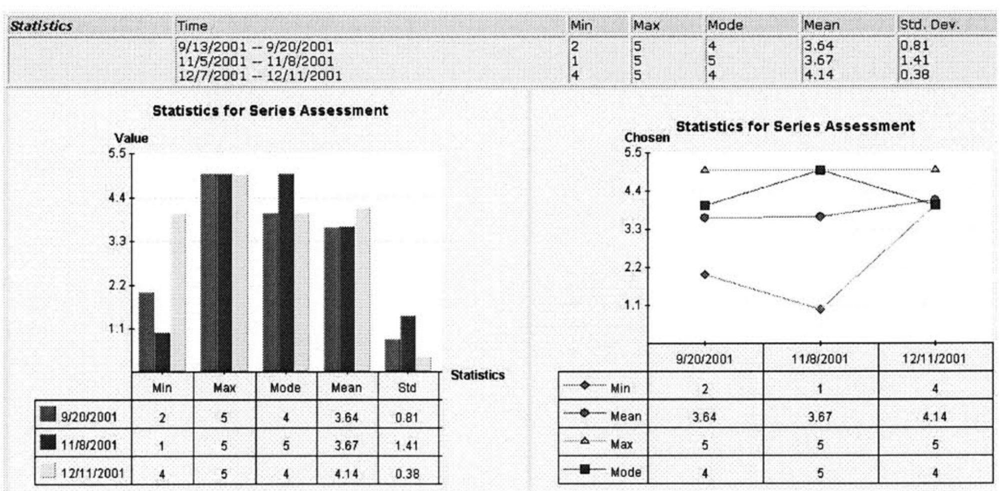


Figure 7-11: Professor Support for Project-based Learning

How difficult was it to understand the professor (choose one):

(1)Extremely difficult (2)Difficult (3)Neither difficult nor easy (4)Easy (5)Extremely easy (6)Can not say

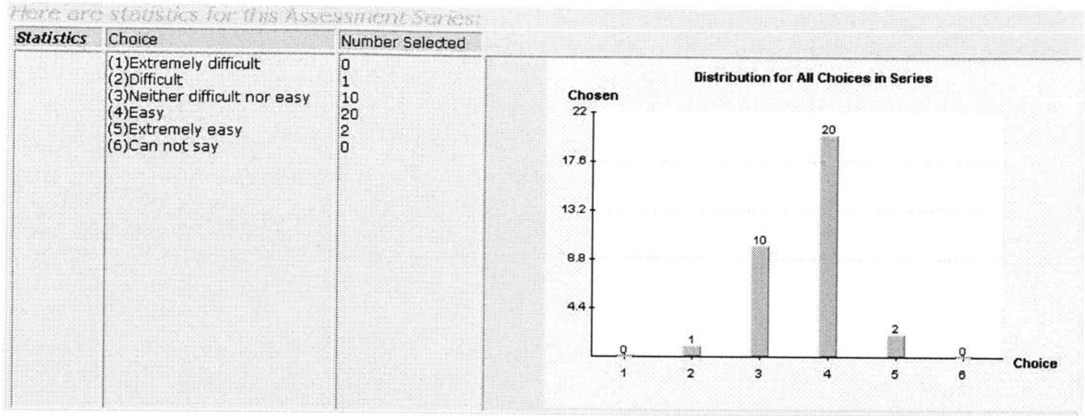


Figure 7-12: Distribution of Team Evaluation about Professor

7.5.4 Facilitator and Infrastructure

Are you satisfied with the current setup of chairs, tables, cameras, and computers/TV screens in the class?

(1)Much less effective (2)No (3)Similar (4)More effective (5)Radically more effective (6)Can not say

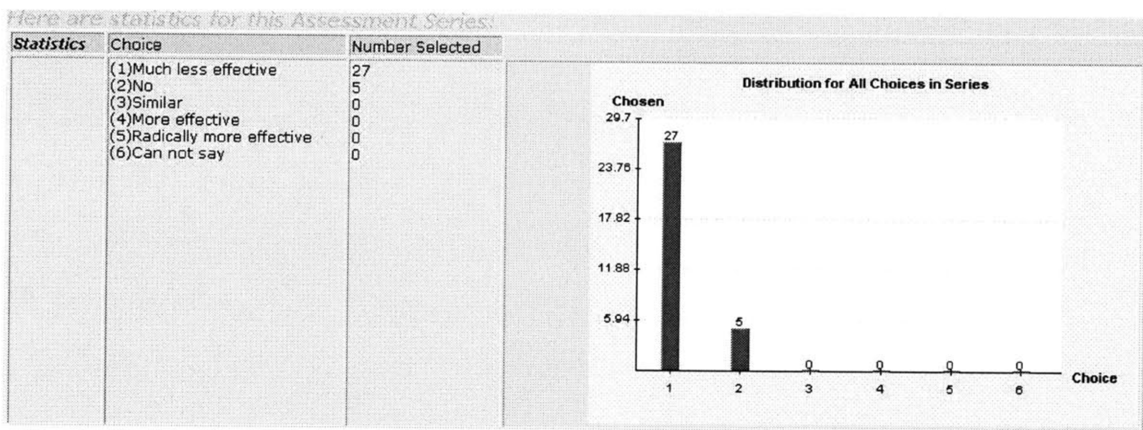


Figure 7-13: Team Infrastructure Satisfaction

Please rank your needs in a project requiring collaboration between geographically separated team members, in order of importance (#1 - most important, #5 - least importance, and so on). If any specific need is not listed, please feel free to add to the list:

(1) Aiding asynchronous communication (Email/Discussions/Web Pages)

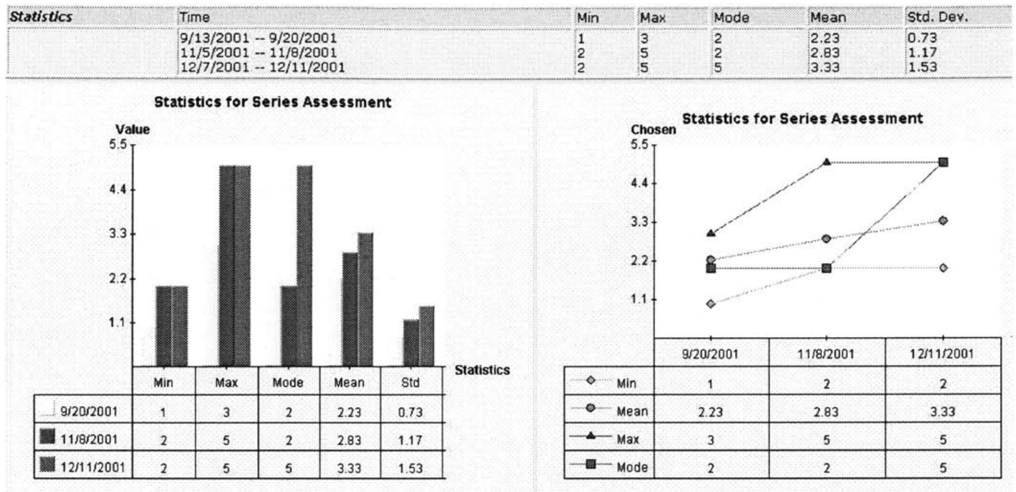


Figure 7-14: Effectiveness of Asynchronous Communication

(2) Creating shared repositories of information

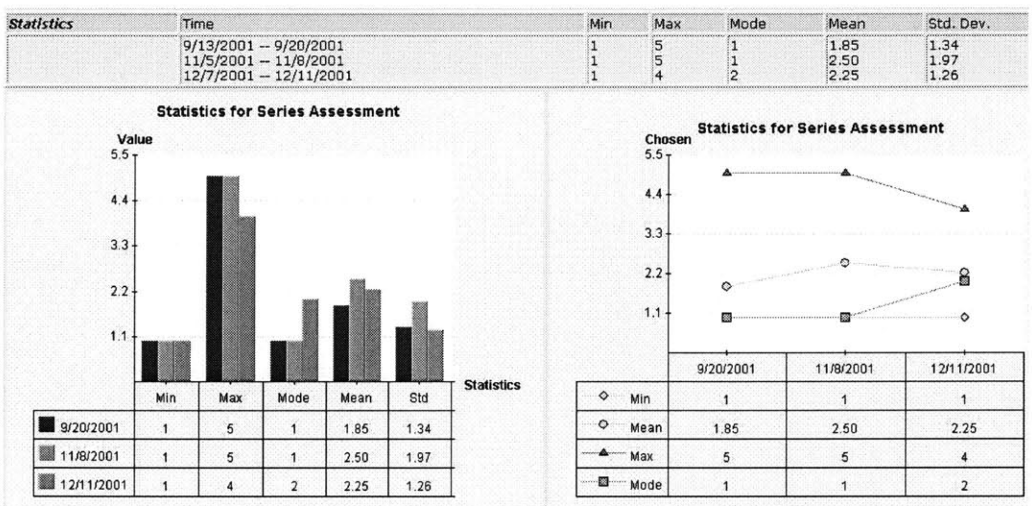
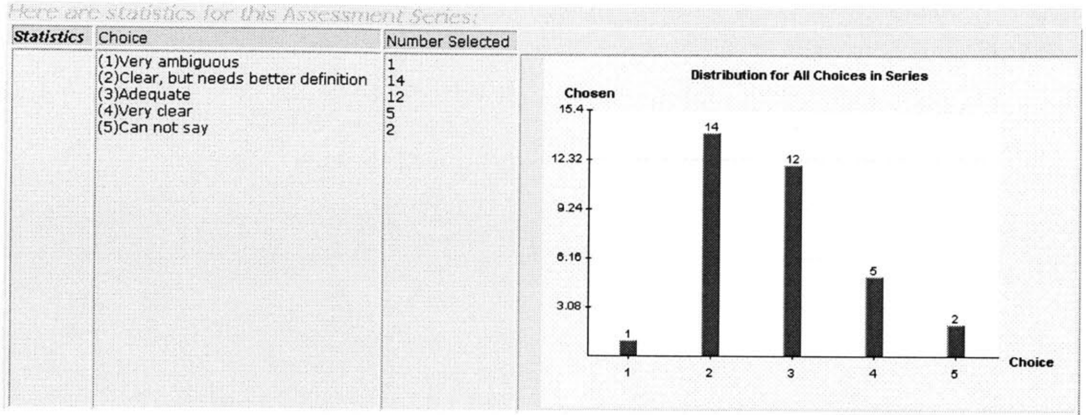


Figure 7-15: Effectiveness of Information Sharing

7.5.5 Collaborative Learning Objective

Team overall objective of the project is: (choose one)

(1)Very ambiguous (2)Clear, but needs better definition (3)Adequate (4)Very clear (5)Can not say



Here are statistics for this Assessment Series:

Statistics	Choice	Number Selected
	(1)Very ambiguous	1
	(2)Clear, but needs better definition	14
	(3)Adequate	12
	(4)Very clear	5
	(5)Can not say	2

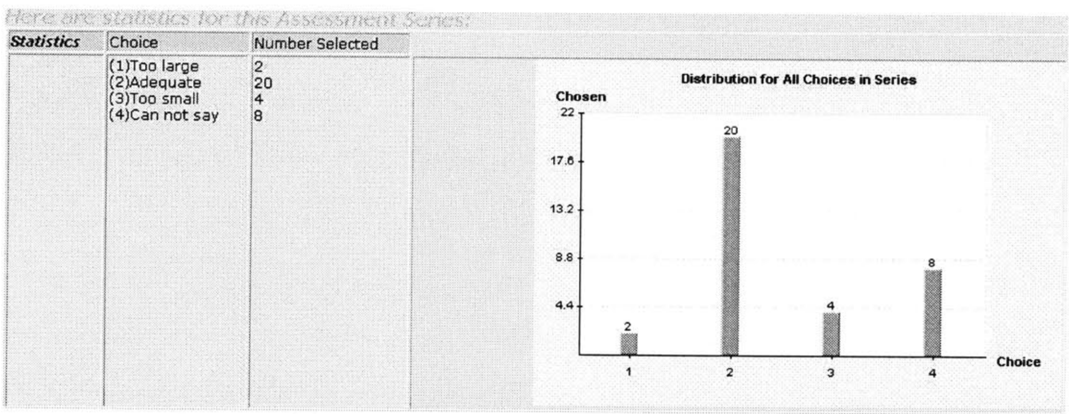
Figure 7-16: Team Learning Objective

7.5.6 Collaborative Learning Team Structure and Processes

Considering the DiSEL class, please give your best estimates:

(1) Size and make up of the team. (Choose one)

(1)Too large (2)Adequate (3)Too small (4)Can not say



Here are statistics for this Assessment Series:

Statistics	Choice	Number Selected
	(1)Too large	2
	(2)Adequate	20
	(3)Too small	4
	(4)Can not say	8

Figure 7-17: Collaborative Learning Team Size

(2) Diversity of the project team. (Choose one)

(1)Too diverse (2)Diversity is clear, but manageable (3)Diversity not so obvious (4)Can not say

Here are statistics for this Assessment Series:

Statistics	Choice	Number Selected
	(1)Too diverse	0
	(2)Diversity is clear, but manageable	21
	(3)Diversity not so obvious	5
	(4)Can not say	8

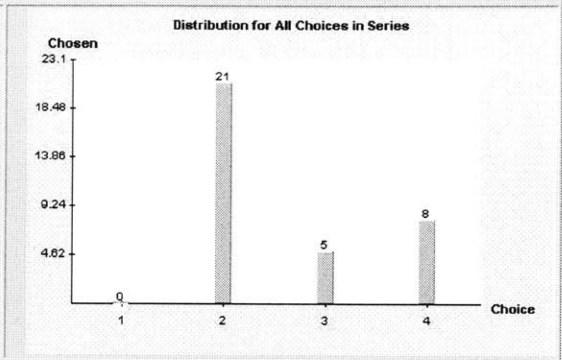


Figure 7-18: Collaborative Learning Team Diversity

(3) Overall, the collaborative learning team meeting process has been: (choose one)

(1)Disappointing (2)Uncontrolled (3)Conflicting (4)Energetic (5)Controlled (6)Perfect (7)Co-operative (8)Can not say

Here are statistics for this Assessment Series:

Statistics	Choice	Number Selected
	(1)Disappointing	1
	(2)Uncontrolled	0
	(3)Conflicting	1
	(4)Energetic	1
	(5)Controlled	9
	(6)Perfect	5
	(7)Co-operative	10
	(8)Can not say	6

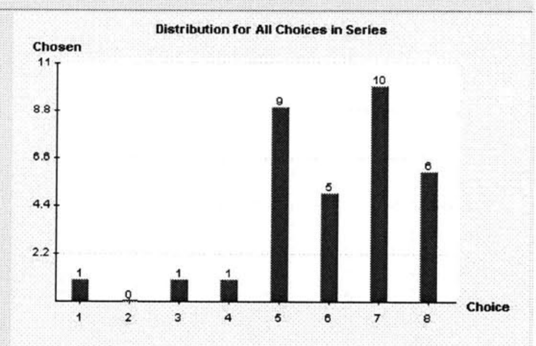


Figure 7-19: Collaborative Learning Team Meeting Process Evaluation

7.5.7 Collaborative Learning Interaction

(1) How focused was the team on the agenda of the meetings?

1: Not focused, as agenda was not very clear. 2: Focused on tasks NOT identified in the meeting agenda. 3: Most of the time spent on tasks identified in the meeting agenda. 4: Completely focused on the tasks set forth in the meeting agenda. 5:if this question is not applicable to you.

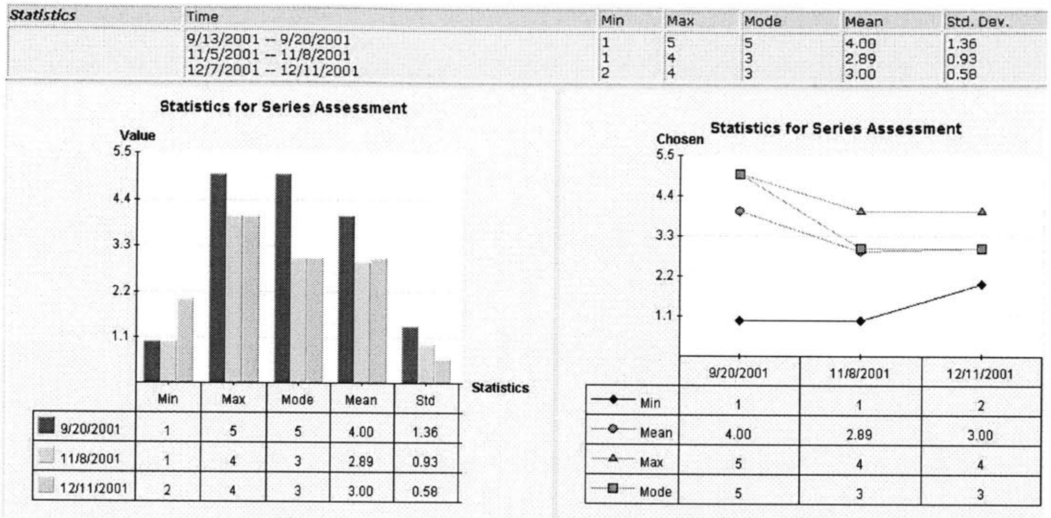


Figure 7-20: Adequacy of Agenda in Team Meetings

(2) How effective was the decision making process during the meetings? 1: Team rarely reached decisions during the meetings. 2: The SAME team members make decisions in all the meetings. 3: A few team members make decisions in most meetings. 4: Decisions are made regularly based on team consensus or everyone input. 5: If this question is not applicable to you.

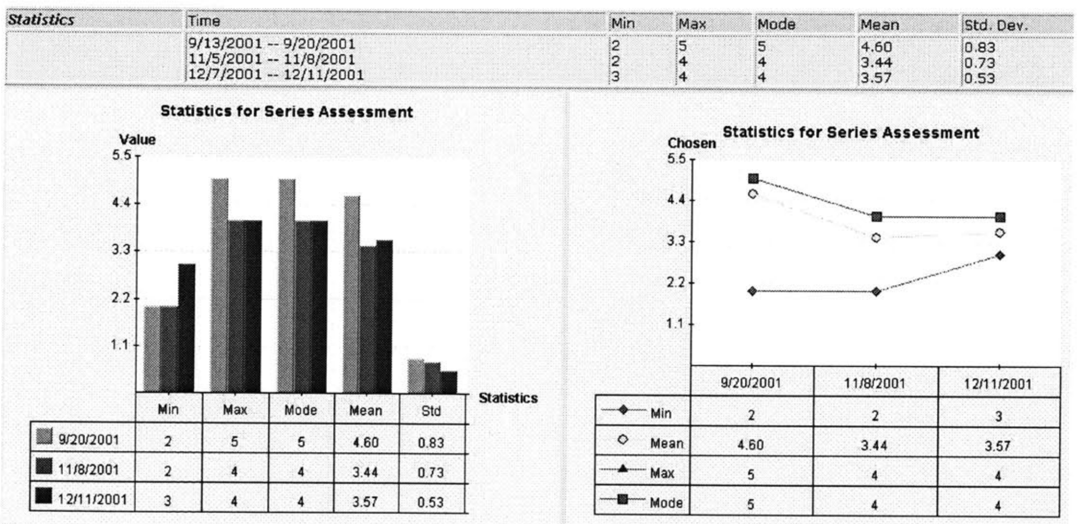


Figure 7-21: Effectiveness of Decision Making Process

(3) How often do you and other team members discuss the level of co-ordination and collaboration that is appropriate to the class?

(1)Never (2)Once in a while (3)Sometimes (4)Quite a bit (5)On a regular basis (6)Can not say

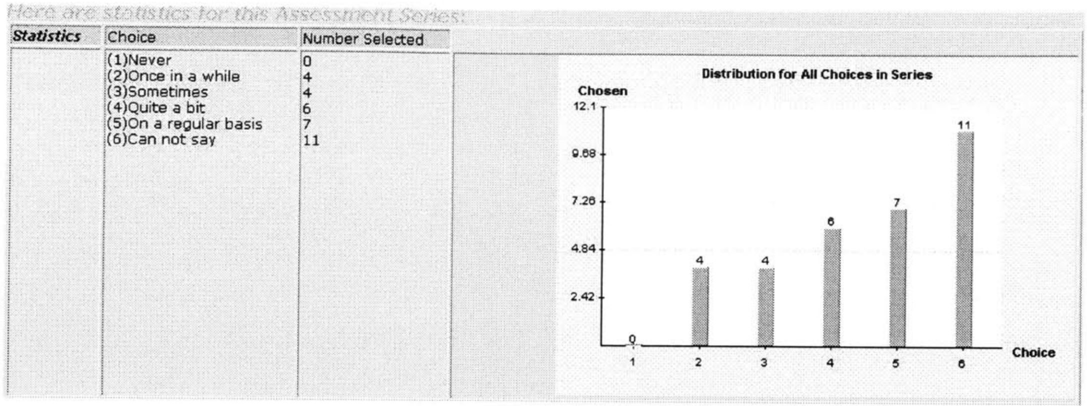


Figure 7-22: Collaborative Learning Discussion

7.5.8 Collaborative Learning Team Support

Considering the DiSEL class, please give your best estimates:

(1) How do you feel about working with your colleagues: (choose one)

(1)Unhappy (2)Concerned (3)Do not care (4)Excited (5)Happy (6)Can not say

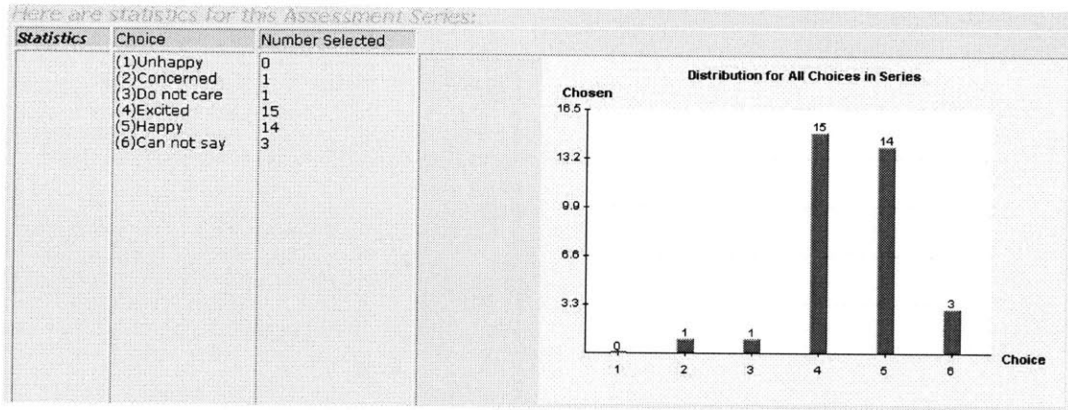


Figure 7-23: Teamwork Satisfaction

(2) Teammate ability to contribute ideas in class: (choose one)

(1)Extremely Poor (2)Poor (3)Decent (4)Good (5)Extremely Good (6)Can not say

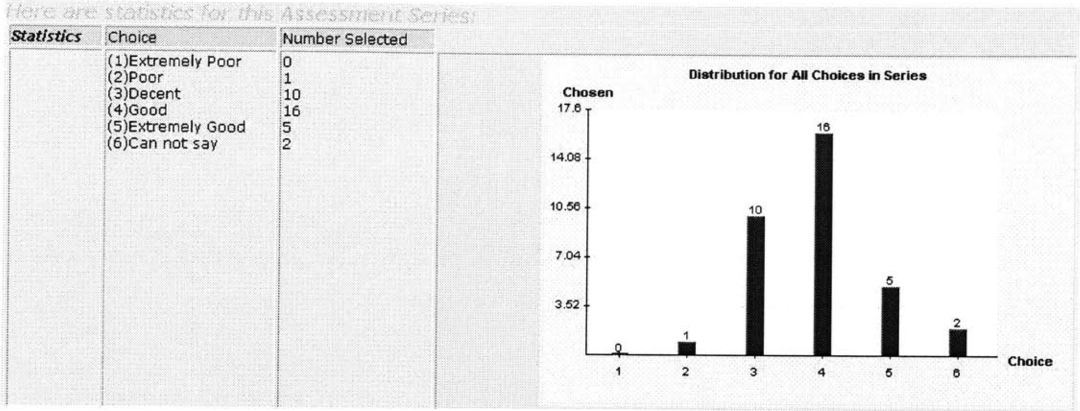


Figure 7-24: Contribution of Individual Knowledge, Skills and Effort to Teamwork

(3) How well was leadership demonstrated during the meetings?

1: Leadership not explicitly demonstrated during most meetings. Team members usually drifted away from the agenda of the meetings. 2: Leadership exhibited by the same team members. 3: Leadership exhibited by few team members in most meetings. 4: Leadership balanced among team members. 5: If this question is not applicable to you.

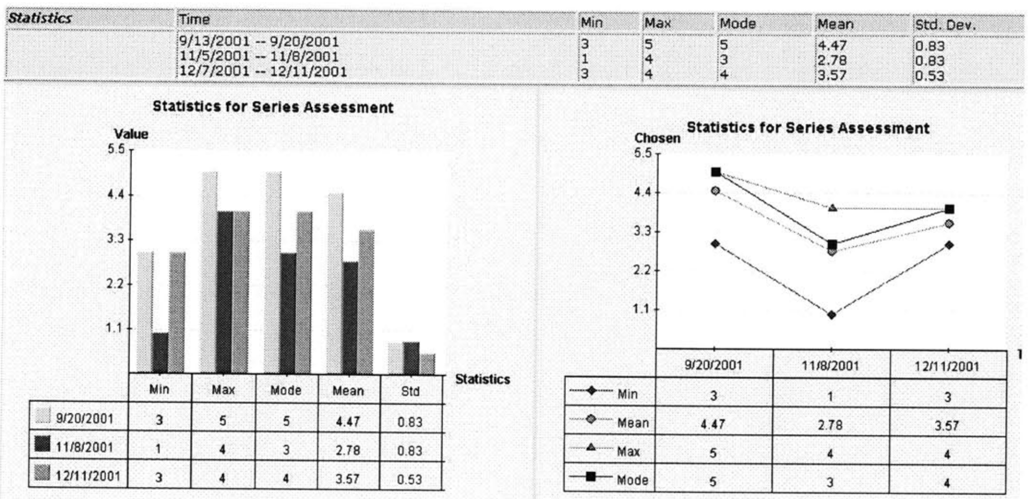


Figure 7-25: Leadership in Teamwork and Learning

7.5.9 Collaborative Learning Peer Assessment

After a period of teamwork for a project or an assignment, peer assessment will be conducted for the team peers to evaluate each other base on their contribution to the collaborative learning. The assessment results can be analyzed over time from several perspectives mentioned in Multi-Dimensional Assessment Model for Peer Assessment in Chapter 4, such as perspective of how the whole team evaluates the individual over time and how an individual evaluates another peer over time.

(1) Which position on the executive, managerial or technical staff do you think is appropriate for this team member based on the work he/she has performed on this part of the assignment?

(1)Chief Executive Officer (2)Chief Technical Officer (3)Chief Financial Officer (4)Project Manager (5)Requirement Analyst (6)System Designer/Architect (7)Software Developer (8)Quality Assurance Engineer (9)Software Tester (10)Marketing Manager (11)Sales Manager (12)Product Manager (13)Configuration Manager (14)Knowledge Manager (15)Quality of Life Manager

Here are statistics for this Assessment Series:

Statistics	Choice	Number Selected
	(1)Chief Executive Officer	1
	(2)Chief Technical Officer	0
	(3)Chief Financial Officer	1
	(4)Requirement Analyst	4
	(5)System Designer/Architect	6
	(6)Software Developer	4
	(7)Project Manager	0
	(8)Quality Assurance Engineer	4
	(9)Software Tester	9
	(10)Marketing Manager	0
	(11)Sales Manager	0
	(12)Product Manager	1
	(13)Configuration Manager	0
	(14)Knowledge Manager	0
	(15)Quality of Life Manager	0

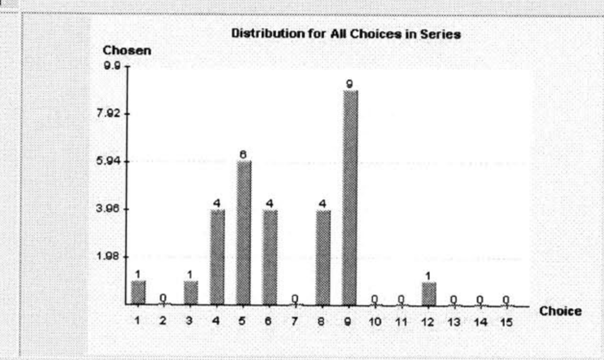
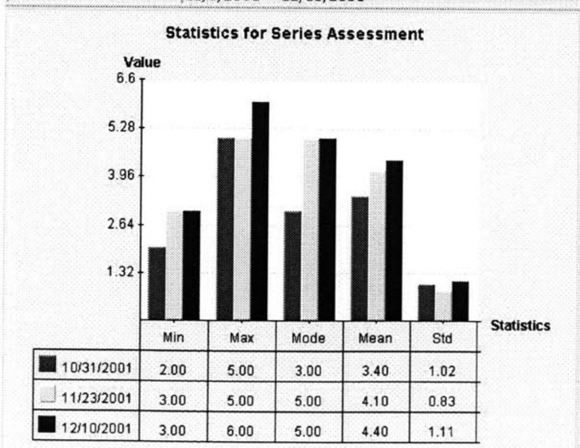


Figure 7-26: Global Team Evaluates Position for an Individual

(2) What salary are you willing to pay this team member for the work he/she performed on this part of the assignment?

Statistics	Time	Min	Max	Mode	Mean	Std. Dev.
	10/29/2001 -- 10/31/2001	2.00	5.00	3.00	3.40	1.02
	11/19/2001 -- 11/23/2001	3.00	5.00	5.00	4.10	0.83
	12/5/2001 -- 12/10/2001	3.00	6.00	5.00	4.40	1.11



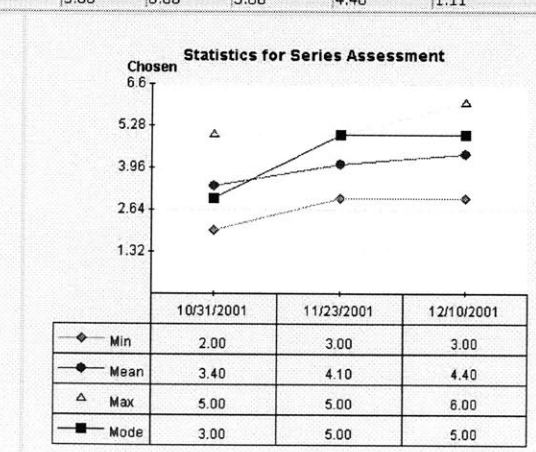


Figure 7-27: Global Team Evaluates an Individual Salary Over Time

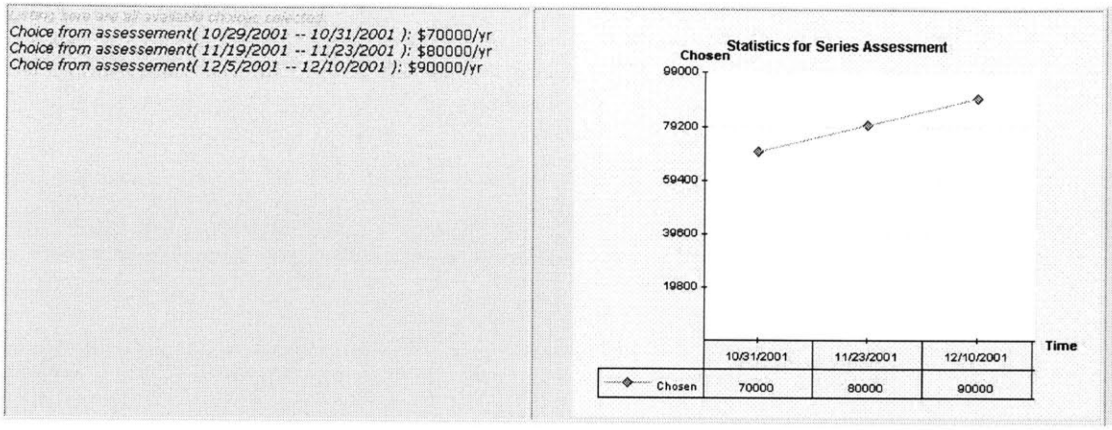


Figure 7-28: Peer Evaluates an Individual Salary Over Time

Based on all the data collected through the collaborative learning assessments for target learning effectiveness variables and analysis from different perspectives, the instructor can identify the barriers to the effectiveness of distributed collaborative learning and team health, monitor the student's individual learning behavior and track the progress, evaluate the individual and team performance for course grading, understand the team learning interaction and collaboration, as well as get feedback about instructor's teaching. Thus, the instructor can adjust the collaborative learning environment dynamics of the class to overcome the identified effectiveness barriers for a more successful distributed collaborative learning and teaching practice.

Chapter 8 Conclusion and Future Research

8.1 Research Summary

Building a virtual distributed collaborative learning and assessment environment is not just a technical issue, but a comprehensive problem that need to understand the underlying educational methodologies and framework, the collaboration and interaction process in collaborative learning, the dynamics of each dimensions that support learning interaction, and barriers to the effectiveness of collaborative learning and team health. Through this research, Teaching For Understanding and Theory One educational methodologies, as well as Project-Based, Collaborative, Distributed and Cognitive Learning (Metacognition) theories have been researched and integrated to form the solid foundation of a pedagogical framework. Based on the pedagogical framework, a Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) has been built up to support the design of computer-supported virtual collaborative learning and assessment environment, with the consideration of effective collaboration and interaction. This framework captures the key dynamic dimensions and reflects the iterative nature of collaborative learning process, which is fulfilled by the three basic components of the framework, which are Distributed Team Interaction (DTI) Model, Virtual Team Collaboration (VTC) Model and Collaborative Learning Assessment (CLA) Model. During the collaborative learning process, Distributed Team Interaction (DTI) Model are used to control the interaction protocols and processes and to deal with learning teams internal dynamics; Collaborative Learning Assessment (CLA) Model creates a structured meeting environment to realize synchronous and asynchronous communication, enables distributed information and application sharing, and coordinates problem solving and decision making through collaboration; meanwhile the multi-dimensional Collaborative Learning Assessment (CLA) Model are designed to keep common focus of the collaborative learning and enhance individual or team learning performance, to assess and improve the effectiveness of collaborative learning and team interaction, and to maintain the health of team cooperation and development throughout the learning cycle.

Besides formulating the Distributed Team Interaction (DTI) Model and Virtual Team Collaboration (VTC) Model from previous separated collaboration research and integrating them into the Distributed Team Collaborative Learning and Assessment Framework, this research put more efforts on building a more flexible Multi-Dimensional Collaborative Learning Assessment Model and effective assessment processes. Following tasks have been accomplished through this research:

- The barriers to the distributed collaborative learning effectiveness and team health have been discovered and categorized that need to be overcome by the framework and guide further design.
- The Collaborative Learning and Assessment Iterative Cycle has been analyzed, which captures the iterative nature of an effective collaborative learning and interaction process in the collaborative environment that includes:
    - Carrying out learning interactions and collaborations in the distributed team interaction space and team virtual collaboration space,
    - Observing the barriers to effective learning and interaction by evaluating the effectiveness variables in the collaborative learning environment through learning assessments,
    - Mapping individual and team performance to Collaborative Learning Team Effectiveness Continuum and comparing them with the desired state,
    - Identifying areas of improvement and making adjustments to remove these barriers in order to increase the learning effectiveness and maintain the team health.
- The Collaborative Learning Team Interaction Effectiveness Continuum has been designed, which is a spiral curve mirroring the real life growth of a virtual learning team, to characterize the maturity of their team practices, to identify potential strengths and weakness

in team practices against a standard and to provide guidelines for learning team to improve team learning effectiveness and performance.

- To evaluate collaborative learning and interaction effectiveness as well as team health, diverse effectiveness and health assessment model elements and variables have been identified and summarized through the research.
- A Multi-Dimensional Collaborative Learning Assessment Model with enhanced Collaborative Learning Assessment Space and Collaborative Learning Assessment Matrix has been defined and created to implement a comprehensive assessment scope to be managed, controlled and analyzed from different perspectives according to the requirements of each collaborative learning assessment.
- Learning Assessment Space and Assessment Matrix can be constructed with different combination of multiple assessment dimensions as useful abstraction and powerful instruments to design an assessment and to analyze the results for specific purpose from various perspectives.
- Effective collaborative assessment process has been clarified and used for the computer-supported collaborative learning assessment support system design and implementation.
- Based on the Multi-Dimensional Collaborative Learning Assessment Model, an easy-used web-based Collaborative Learning Assessment Support System (CLASS) has been designed with pedagogical framework and educational theories' support to provide various functionalities for an effective collaborative assessment process. The system is designed using multi-tiered thin-client web-based Application Server architecture and implemented with advanced software standards and technologies to provide relatively high flexibility, scalability, reliability and performance.
- CLASS system been tested and used for "real world" teaching and collaborative learning practices in MIT Distributed Systems Engineering Lab (DiSEL) course 1.118 throughout the collaborative learning iterative cycle. Based on all the data collected through various assessments for target learning effectiveness variables and analysis from different perspectives, the instructor could monitor the student's individual learning behavior and track the progress, understand the team learning interaction and collaboration, identify and overcome the barriers to the effectiveness of distributed collaborative learning and team health for a more successful collaborative learning and teaching practice.

8.2 Future Research

The concepts of Distributed Team Virtual Collaborative Learning and Assessment Framework (DTVCLAF) and Collaborative Learning Assessment Model have been introduced in the research for distributed collaborative learning, and basic models of the framework has been analyzed and built to some extend under the effort of research at MIT Intelligent Engineering Systems Laboratory (IESL). To realize more effective and comprehensive assessment to support collaborative learning, there are more issues have been identified and need to be researched for future work.

8.2.1 More Flexible Assessment Model

Although a multi-dimensional Collaborative Learning Assessment Model with Assessment Space and Assessment Matrix has been developed, as well as a tested working prototype has been implemented through the research, the assessment model is still evolving in the following aspects considering the flexibility of the system

- More flexible user interface and system navigation
- More flexible question model, considering the question types, question styles, question reusability and question relocation
- More flexible and effective assessment control, considering assessment branching and question sequence randomization
- More flexible data exchange, considering the online assessment data import and export, interface with external analysis system
- More flexible statistical analysis, considering more comprehensive and efficient multi-dimensional data analysis, by probable techniques of online Data Cleaning, Data Warehousing and Data Mining. Assessment Space evolves from single team single objective assessment support to multiple teams multiple objectives assessment support.

8.2.2 More Interactive Assessment Model

As Collaborative Active Learning Environment are under research aimed at improving learning in engineering education through a combination of computer-based simulation. Various simulations are created to represent the abstract physical laws for easier understanding or phenomena that are hard to observe in reality. The simulation tools can be used to allow students to observe the performance of natural and artificial structures and systems. Students learn by observing the performance as they change characteristics of systems and structures and of boundary conditions. They learn actively by being required to make predictions and then being able to compare them to the behavior. Whereas, the interactive learning with simulation tools traditionally turns out to be an individual self-learning behavior at one time and lack of recording and monitoring in the distributed environment. Thus, a more interactive learning assessment model needs to be developed to support interactive learning in the distributed collaborative environment. This model should enable the system to control the various individually distributed simulation tools (created with Applet or Flash) and assess the dispersed participants' learning through their interactions with the simulation tools. This assessment model can help the instructor to monitor the students' interactions with simulations, to record the students' interactive learning process and the progress of understanding, and to analyze student and team learning behavior with the simulation tools.

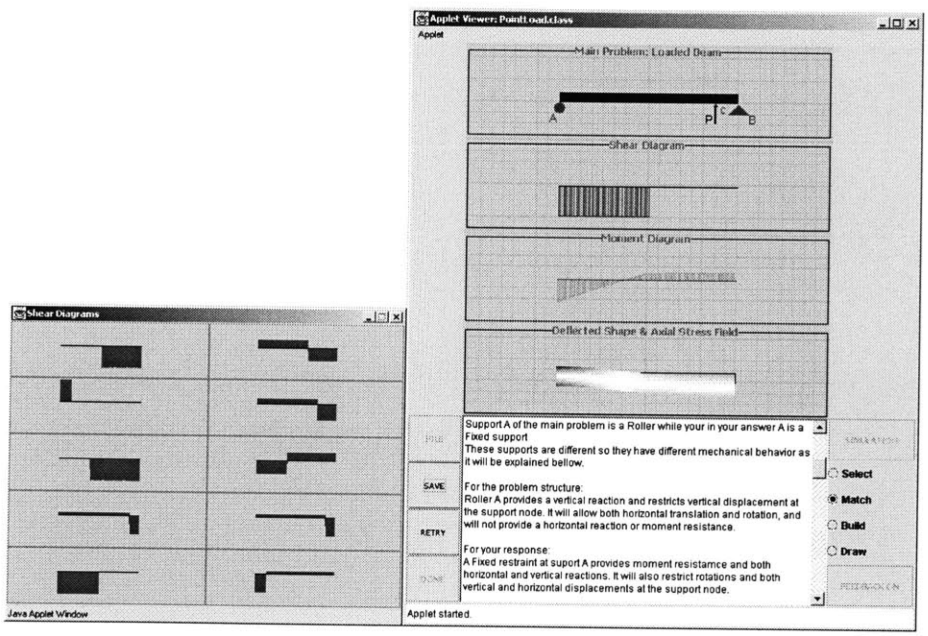


Figure 8-1: Interactive Simulation Tool (Applet)

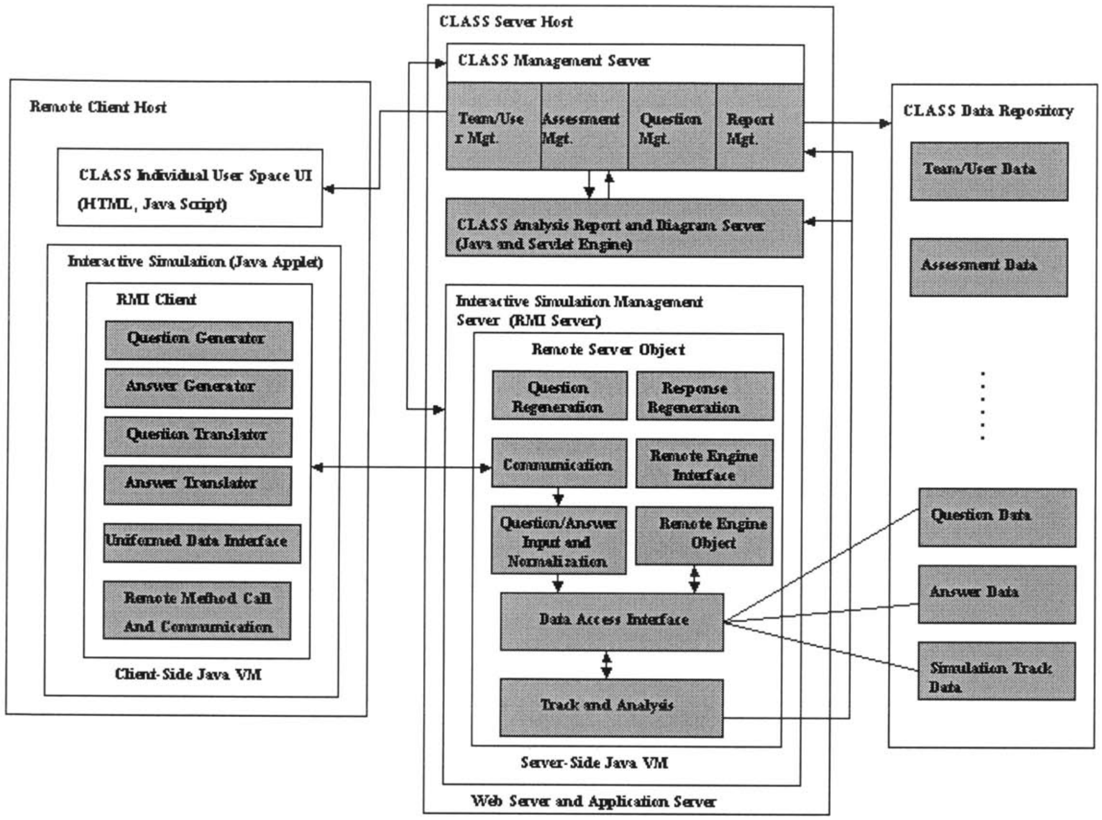


Figure 8-2: Interactive Simulation Management Server

The Interactive Learning Assessment Model and corresponding Interactive Simulation Management Server should support:

- Multimedia and simulation questions, besides textual and graphical questions
- Communication and messaging with distributed simulation tools
- Remote control for simulation tools
- Distributed individual interaction and responses recording
- Interaction process and responses regeneration and representation
- Evolving from individual interactive behavior to collaborative interactive behavior monitoring
- Evolving from single time simulation interaction analysis to progressive interaction process analysis

A sample design for the Interactive Simulation Management Server has been conducted shown in Figure 8-2, using Java Remote Method Invocation (RMI) Technology (Sun, 2002) to support object-oriented distributed computing for collaborative learning assessment. This server needs to interact and cooperate with other server components in the assessment system to realize the interactive assessment functionality.

8.2.3 More Intelligent Assessment Model

With the advent and excitement in the area of agent-based systems that has resulted from the confluence of a variety of research disciplines and technologies, notably AI, object-oriented programming, human computer interfaces, and networking, the virtual collaborative learning and assessment environment can evolve to a new generation with intelligence. For more effective and intelligent assessment to assist collaborative learning in the virtual computer supported environment, another Intelligent Assessment Model with Intelligent Assessment Advisor needs to be researched based on intelligent software agent and AI technologies.

An intelligent agent is a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to affect what it senses in the future (Stan Franklin, 1996). Although there have been many attempts at defining an agent and no agreed-on definition exists yet, there seems to be a convergence of opinion that an agent is a software entity with the four main characteristics (Katia, 1998):

- **Autonomy:** the agent can operate without the direct intervention of humans or others, and have some kind of control of their actions and internal state;
- **Situatedness:** the agent receives some form of sensory input from its environment, and it performs some action that changes its environment in some way;
- **Adaptivity:** the agent is capable of reacting flexibly to changes in its environment; taking goal-directed initiative, when appropriate; and learning from its own experience, its environment and interactions with others;
- **Sociability:** the agent is capable of interacting in a peer-to-peer manner with other agents or humans via some kind of agent-communication language.

The Intelligent Assessment Advisor in Intelligent Assessment Model requires aspects of periodic action, spontaneous execution, and initiative of leaning assessment environment, in that the agent must be able to take preemptive or independent actions that will eventually benefit the users (students). The Intelligent Assessment Model enhances the collaborative learning and assessment environment by:

- Providing intelligent, autonomous assessment advisor to control the whole assessment process and monitor the interaction in the collaborative learning environment
- Managing the interaction with agents of other system components (multi-agent system) (Peter Stone, 1996)

- Tracking students' learning process and answering behavior for system learning
- Analyzing students' responses to assessment questions to identify their understanding of objective knowledge
- Classifying the results and training the agent to understand the student's learning behavior
- Generating questions of different difficulty level intelligently on fly based on the student's level of understanding
- Controlling intelligent question skip and assessment branches
- Identifying individual or team collaborative learning effectiveness and performance by analyzing assessment results, and positioning individual or team in the evaluation continuum for future assessment creation
- Creating and inviting assessment automatically for an individual or a team, according to the learning objective, current learning stages in the process and individual or team current learning performance and progress

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APPENDIX 1: Expectations Rubric

Table Appendix -1Expectations Rubric

Learning Categories (Generative Topics)	Understanding Goals *Students will understand ...*	Performances of Understanding and Ongoing Assessment
1. Life Cycle of System Development	How to re-engineer or upgrade a system already developed How to see what similar products are already out there The different system development models The problems inherent with distributed system development The different and necessary roles involved in a team of system developers	Students show an appreciation for all the roles of the system development process in their course work and participation. Students can identify and explain which role is responsible for which jobs and why in their course work and participation. Students show an ability to identify the various types of system development cycles.
Requirements Analysis	Students will understand how to develop: Good questionnaires for users and/or good interview questions Case scenarios of what users would want Measurements for those functions the users want, to establish priorities Ways to determine user satisfaction A requirements document	Performances: Develops a questionnaire/interview questions for market experts Develops case scenarios Develops good measurements of the requirements and user satisfaction Develops a Requirements Document Performs Technical reviews
Design	Students will understand how to: Take the requirements of the system (developed by the Requirements Analysis team) and develop a model of how those functions are going to be represented and how they should perform in a program Evaluate the trade-offs of the various system functions (storage versus time of execution versus network distribution and load time) Create a flexible and open model that can easily be expanded extensively Define the architecture of this system for implementation	Performances: Develops a viable model of how the requirements will be a part of the design Determines the trade-offs of system functions Creates a flexible model Defines the system architecture
Project Management	Students will understand how to: Develop a good working plan for the execution of the whole system development process Determine resource requirements (including time and software/hardware) Analyze risk — foresee implementation problems Set realistic milestones Work to coordinate team member efforts (create team harmony) Raise flags before problems become nightmares Present the product being developed to an external audience	Performances: Develops a working production plan as well as a business plan Determines resource requirements Analyzes risk and foresees implementation problems Sets realistic milestones Facilitates harmony between team members

Learning Categories (Generative Topics)	Understanding Goals *Students will understand ...*	Performances of Understanding and Ongoing Assessment
Knowledge Manager	Students will understand how to: Create a framework for documentation and product production Check for facts and assumptions Create a good repository for product memory Maintain the evolution of documents Develop a good searching mechanism of the final product and all associated information	Performances: Creates a framework for documentation, product production, and tracking Reviews documents well for facts and assumptions Produces a memory repository Develops a search mechanism of the final product and associated information
Quality Assurance	Students will understand how to: Monitor both product and process compliance to good practice and standards (relevant information is recorded properly, and assumptions documented.) Create cases that test the product process to assure that good development practices happen Highlight problems in the early phases Produce statistical results of problems and provide guidance for solutions Develop a good plan for resolving problems, identifying by when and whom a problem should be resolved Assure that the system is compliant to user requirements Assure that the process and the product can be extended Maintain a low overhead during the development process and production of the system Differentiate and prepare technical reviews (walkthroughs, audits, peer reviews and inspections), recognize when to use which, and the advantages and disadvantages of each.	Performances: Monitors the product process and assures compliance to good practice Creates cases to test the product process and thereby identifies problems in the product Uses statistical analysis to suggest ways to resolve identified problems Assures low overhead costs during the development of the system Sets-Up and Participates well in Product and Process Walkthroughs, Inspections, Audits and Peer Reviews
Programming	Students will understand how to: Implement design plans and develop executable system that satisfies the design Devise a plan by which code can be developed by multiple programmers in distributed locations Handle code versioning Develop good incremental integration plan Comments in the code so anyone can follow them Create good documentation regarding the code	Performances: Implements design plans Develops executable system Codes from distributed programmers are well integrated and can be easily modified Documentation of and Comments on code are understandable A reliable programming language is used
Configuration Management	Students will understand how to: Identify the configuration of a production system Control all Configuration Changes Record and Trace all changes in a system Verify all changes via auditing and reporting	Performances: Makes sure production processes are successful and repeatable Tracks and controls all versions of the system during the development process so all project members can get up-to-date information on the product's status Minimizes production costs

Learning Categories (Generative Topics)	Understanding Goals *Students will understand ...*	Performances of Understanding and Ongoing Assessment
2. Entrepreneurial Skills	Students will understand how to: Design, develop and sell an idea in nine months Define their local and global market niche Determine their revenue source Determine product maturity to establish the time for venture capitalists' involvement and second phase support (when money needs to be coming in, when money needs to be going out) Define their product Define their market share Present a business idea to founders Create a product portfolio that shows the service plan Organize themselves so creativity flows Develop a business plan	Students will demonstrate their understanding by: Correctly applying for funding (1K or 50K) Presenting their business plan
3. Collaboration	Students will understand how to: Define when a group is working and when it is not Discern when: Tasks need to be done by divide and conquer Tasks need to be done with everyone's' participation One person needs to champion some task through completion Know peers' faces and names Create a good mental model of what their fellow group members can do and can't do well and how reliable they are Create trust in the group	Students will show their understanding by: Appropriately working together by building on each other's ideas Knowing when a group is working and when it is not (Appropriately addressing situations where the group is functional and when it is not functional) Appropriately determining when a task needs to be done by dividing and conquering, everyone participating, or when one person needs to champion some task through to completion Knowing peers' faces and names Creating a good mental model of what their fellow group members can do and can't do well and how reliable they are Creating trust in the group Setting up the expectations of the group
4. Collective Memory	Students will understand how to: Develop a memory of the system development process so that others can understand the experience and build on it Recognize benefits and limitations of overhead costs Amortize project costs Reflect on past experience and other projects that have taken less time	Students will show their understanding by: Storing their work in ways that are understandable and sharable Developing a database of work completed Using a repository of the work completed in the class for the project