Computer Supported Collaborative Knowledge Construction Learning Environment

A thesis submitted to
the Faculty of Computer Science & Information Technology
University of Malaya
in Fulfillment of the Requirements for
the Degree of Master of Computer Science

by

SITI SORAYA BINTI ABDUL RAHMAN
(WGA99059)

2002

Under the supervision of

Assoc. Prof. Dr. Siti Salwah Salim

ABSTRACT

The current interest in the use of information and communication technology (ICT) has made it feasible to consider constructivism principles within the context of the technology-mediated higher education. This is primarily due to advances in ICT resulting in an effective means to implement constructivism principles, which would be difficult to accomplish with other media. In this development, computers play an important role. Computer Supported Collaborative Learning (CSCL), especially, offers promising innovations and tools for restructuring teaching-learning processes to prepare students for education today. An attempt is made in this thesis to explore the current pedagogical perspectives of learning on educational practices particularly the constructivism and collaborative learning principles. The combination of these principles leads the development of higher education towards the achievement of their main current goals hence prepares individuals for a lifelong learning. This thesis describes and exemplifies a theoretically based approach to the design of collaborative knowledge construction learning environment. First, the detailed studies of learning theories on educational practices particularly cognitive constructivism, social constructivism and collaborative learning was disposed by introducing a model, named Collaborative Knowledge Construction process model (COKC) to direct student learning through collaborative knowledge construction activities at the levels of Articulation, Comparison, Argumentation, Clarification, Negotiation, and Integration. Second, a conceptual framework for the application of Knowledge Construction Space (KC-Space) developed from this model has also been proposed. Third, this framework has been used as a basis for the design and development of KC-Space learning environment. Next the KC-Space has been evaluated and research findings from the pilot study are reported to be satisfactory. Finally, it highlights the essential contributions of this research and outlines promising future research directions.

ACKNOWLEDGEMENT

I wish to express my deepest gratitude to my supervisor, Assoc. Prof. Dr. Siti Salwah Salim for her enthusiasm, inspirations, advice and guidance throughout the entire research. This entire research project would not be possible without her continuous support, and I am grateful for her confidence in me.

I am equally thankful to my mother and father, Puan Halina Abdullah and Encik Abdul Rahman Ngah for their constant support throughout my studies and research. I would also like to thank my husband, Encik Mohd Adnin Hasan for his motivations and encouragement.

Finally, I am grateful to everyone who has been working hard in the Human Computer Interaction Lab. All of them have helped me in one way or another during the course of the research. I enormously enjoy the excitements of the research due to the involvement from all of them.

CONTENTS

LISTS OF FIGURES

LISTS OF TABLES

Chapter 1

Introduction

Knowledge construction (Constructivism principles) in the most general sense means a learning process, where people construct their own understanding and knowledge of the world, through experiencing things, reflecting on those experiences. When we encounter something new, we have to reconcile it with our current state of understandings, maybe changing what we believe to accommodate new experience, or maybe assimilate to adopt new information that fits into our prior understandings. To do this, we must ask questions, explore, assess what we know, invent the solutions, and try to form ideas and hypotheses. Knowledge construction recognizes the construction of new understandings as a combination of prior knowledge, the context and the beliefs and attitudes an individual brings to the experience of learning.

One important part and the keyword for the 'knowledge construction' is the collaborative learning and especially the discipline of Computer-supported collaborative learning (CSCL). Computer-supported collaborative learning (CSCL) has emerged out of wider research into computer-supported collaborative work (CSCW) and collaborative learning. The two fields have much in common and we can benefit greatly from sharing their understandings on how technology can support group interaction. The differences between CSCW and CSCL are that CSCW tends to relate to working life, CSCL to the life of education setting; CSCW tends to focus on the techniques of communication themselves, while CSCL focuses on what is being communicated; the purpose of CSCW is to facilitate group communication and productivity, and while the main purpose of CSCL is to scaffold and support students in learning together effectively by the use of computer supported systems specially designed to facilitate group process and collaboration. CSCW and CSCL both are based on the same premise where computer supported systems support and facilitate group process and group dynamics in ways that are not achievable by face-to-face, but they are not designed to replace face-to-face communication. These systems meant to be used by multiple students working at the same workstation or in networked machines. These systems can support communicating ideas and information, accessing information and documents, and providing feedback on problem-solving activities. (Excerpted from CSCL Theories by D.Hsiao).

There are number of theories which contribute to the understanding of CSCL, namely sociocultural theory (based on Vygotsky's Zone of Proximal Development), constructivism theory, self-regulation learning, situated cognition, cognitive apprenticeship, problem-based learning (Cognition and Technology Group at Vanderbilt), cognitive flexibility theory (Spiro et al.'s, 1988), and distributed cognition (Salomon et al.'s, 1992). These theories are based on the same underlying assumptions that individuals are active agents that they are purposefully seeking and constructing knowledge (Excerpted from CSCL Theories by D.Hsiao).

Recently, there are lots of empirical researches available on collaborative knowledge construction in the field of CSCL. Nevertheless, many of these researches are limited to focus on either individuals (cognitive) or social (group) (Salo 2001).

In general, the aim of the research is to address the question, "How to support the students working together in a group to achieve shared knowledge constructed?" This question can be rephrased more specifically as, "How the individual constructed knowledge, the social co-constructed knowledge, the processes of collaborative knowledge construction, scaffolding provided by different form of collaborative tools can be used to facilitate knowledge construction in collaborative settings?"

This research responds the above questions with the following features:

- Six phases of process model to guide students through the collaborative knowledge construction process named COKC (**Co**llaborative **K**nowledge **C**onstruction).
- KC-Space (**K**nowledge **C**onstruction Space) learning environment that integrates COKC process model.
- An experiment that provide empirical insights on the feasibility of executing the collaborative knowledge construction process using KC-Space.

1.1 Overview of the thesis

The thesis presents and exemplifies a theoretically based approach to collaborative knowledge construction by introducing a COKC process model. The COKC process model is founded on three main learning theories, namely cognitive constructivism, social constructivism, collaborative learning and is formulated based on Stahl's model of collaborative knowledge-building. It also describes KC-Space learning environment that embodies such a conceptual approach. Furthermore, it discusses the experience from two usage sessions of KC-Space learning environment by two groups of higher degree students. This usage indicates that KC-Space is useful environment to support knowledge construction in collaborative settings.

This thesis begins with the descriptions of the main motivations behind the current work. Then, it introduces the objectives of this research, which is followed by the research methodology. The scope and limitations are highlighted next. Finally, it concludes with an overview of the organization for the remainder of this thesis.

1.2 Research motivation

This research is motivated by two main trends, namely the technological and the theoretical. The former is the continued interest in the use of information and communication technology (ICT). The latter is the current pedagogical perspectives of learning that is the constructivism principles.

Information and communication technology

The changing nature of information and communication technology (ICT) has critical impacts on the delivery of education today. Also is the nature of educational institutions as it enters an age of knowledge. As a consequence, educational institutions are motivated to find better options for pedagogical approach to cope with the challenges of an emerging knowledge society and to capitalize the benefits of modern ICT. In this educational development computers play an important role. CSCL, especially, offers promising innovations and tools for restructuring teaching-learning processes to prepare students for education today (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). "*CSCL environments have a potential for supporting the current pedagogical perspectives of learning such as active* *learning, group collaborating and knowledge construction"* (Kreijns. K & Kirschner. P.A., 2001). The model of instruction underlying work in CSCL is termed "collaborative learning". Collaborative learning refers to an instructional method whereby students are encouraged to work together on problem-solving or learning tasks. Various researches on collaborative learning have indicated several positive effects: enhanced individual learning outcomes; and higher group performance especially with regard to knowledge construction (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). Despite of the extensive literature on the social benefits of collaborative learning, many researchers have tried to use the emerging computer and communication technologies to construct effective collaborative learning systems.

There are a number of systems approximating what can be called CSCL system currently available. However as far as CSCL is concerned, the current approaches used in collaborative learning system are less than adequate. Most of the systems do not completely fulfil their potential in supporting collaborative knowledge construction.

Constructivism principles within the context of the technology-mediated higher education

The advancement in ICT has made it feasible to consider constructivism principles within the context of the technology-mediated higher education (Blanchette & Kanuka, 1999 in Kanuka, Heather & Anderson, Terry, 1999). This is due primarily to the ability of the computer to provide an interactive environment creating *"an* *effective means for implementing constructivist strategies that would be difficult to accomplish in other media*" (Driscoll, 1994).

Constructivism has emerged from the work of psychologists and educators such as (Piaget, J., 1970) and (Vygotsky, L., 1978). These theories underscore the significance of constructing knowledge through both individual and social context of a community. The collaborative knowledge construction process results in shared knowledge and understanding that then allows for both individual and a group of individuals to leave the situation changed. Shared knowledge represents the common understanding of a group of individuals working together; the active construction of shared knowledge lead to increased learning and problem solving. Three requirements are needed during the collaborative knowledge construction process: First, opportunities for student to collaborate, to articulate and to reflect must be provided to help students to think deeply regarding the problems they are working on; second, shared knowledge should be represented clearly (Pfister, H.-R., Wessner, M., Holmer, T., Steinmetz, R., 1999); thirdly, multiple stakeholders' perspectives need to be reconciled and represented explicitly (Jonassen, 1993). As far as this research is concerned, there is no research as yet that has explicitly addressed such three requirements mentioned above. These problems are intrinsic and also essential to collaborative knowledge construction.

Though this research may not lead to definite answers to the above and many other related questions, yet it does represent the first step toward the ultimate understanding of such important issue.

1.3 Research objectives

The objectives of this research are summarized as follows:

i. To propose a COKC process model to guide students through the collaborative knowledge construction process. The process model enables students to articulate ideas, to compare them with others, to argue and critique each individual's perspective, to clarify any disagreement or misunderstanding, to negotiate and to integrate other student's ideas with their own.

ii. To develop a KC-Space learning environment that integrates COKC process model, an instrumentation mechanism.

iii. To evaluate the effectiveness of KC-Space in supporting student learning through collaborative knowledge construction process.

1.4 Research methodology

The research methodology involves the following steps:

i. Identifying and reviewing a number of important learning theories that particularly relevant to the design of collaborative knowledge construction learning environment.

ii. Conducting a survey of four collaborative knowledge construction systems namely, CLARE, KIE, Web Knowledge Forum and CoVis. Particularly, the selection of the systems was based on two criteria. First, all four systems was designed to achieved a constructivist learning community. Second, all the systems fall into a special type computer based learning environment termed the collaborative knowledge construction learning environment. The survey is conducted in order to get a good understanding of the above-mentioned systems and to determine these systems according to the theoretical aims they attempt to satisfy. A good understanding of existing collaborative knowledge construction systems offers a clear idea about the structure of KC-Space.

iii. Scrutinising the Stahl's models developed for collaborative knowledge construction.

iv. Proposing a COKC process model and framework for the application of this model. The framework provides a basis for guiding development of computer supported learning environment called the KC-Space.

v. Measuring the success of KC-Space by conducting a pilot study using some users. KC-Space is going to be evaluated by collecting the users' feedback on KC-Space using a questionnaire.

1.5 Scope and limitations

In conjunction with the objectives of the research, the scope of the research is defined in order to provide a general guideline to the range and depth of the research. The following statements summarize the scope of the research in accordance with the stated objectives:

i. Collaborative knowledge construction is a complex learning activity to study and support. This research does not attempt to address all-important aspects of the subject. Other issues such as the kind and extent of knowledge co-constructed during and after collaboration are beyond the scope of this thesis.

ii. Countless hours of searching the journals, conference papers and Internet revealed that not many process models for collaborative knowledge construction are being developed. Stahl's collaborative knowledge-building model (Stahl, 2000) is the only generic process model available to date, which provides structured process-level that foster collaborative knowledge construction. Stahl's generic model so therefore is the main focus for this research. Several works concerning specific models for collaborative learning environment development are beyond the scope of the thesis. Other model of instructional design within the context of instructional technology will not be covered.

iii. Constructivism conception of learning that engages the student in task, which facilitates collaborative knowledge construction is most effective for an education of higher learning (Jonassen et al's, 1993). Thus, for the KC-Space evaluation purposes, the pilot study is limited to focus on higher degree student. Other educational instances will not be evaluated.

iv. At the system level, KC-Space does not have certain advanced functionalities found in other collaborative knowledge construction systems. Instead, KC-Space is intended as prototypes to show a proof of concept of how such collaborative knowledge construction tools can be built to support collaborative knowledge construction activities, and are not necessary robust or bug-free.

1.6 Thesis Organization

Chapter 2 covers the research related work on learning theories that particularly relevant to the design of collaborative knowledge construction learning environment. Specifically, the chapter review research related to the following areas: Constructivism theories of learning covering cognitive and social constructivism, Collaborative learning theory, and existing collaborative knowledge construction tools and process models.

Chapter 3 discusses the proposed process model called COKC, which is designed specifically to facilitate collaborative knowledge construction process. The framework for the design and development of KC-Space presented by COKC process model is then discussed. The final section of the chapter briefly discusses the KC-Space learning environment and the tools support, which implements the COKC model.

Chapter 4 describes the analysis and design of KC-Space. The required analysis, KC-Space object-oriented analysis and design and some aspects of the user interface design will then be presented in detail.

Chapter 5 presents the implementation and execution of KC-Space. It also shows how to use KC-Space in executing the collaborative knowledge construction process.

Chapter 6 describes the evaluation process and the results obtained from the pilot study.

Chapter 7 concludes the content and the contribution of this thesis. It also presents conclusions and some suggestions for possible future research directions.

Chapter 2

Literature Review

Chapter 2 covers research related work on learning theories that particularly relevant to the design of collaborative knowledge construction learning environment. Specifically, the chapter review research related to the following areas:

i. Knowledge construction
ii. The constructivism theory of learning and collaborative learning.
iii. Existing collaborative knowledge construction systems and process model

2.1 Knowledge construction

Constructing knowledge involves the opportunity to critically analyze information, dialogue with others about its meaning, reflect upon how the information fits within a personal belief and value structure, and arrive at a meaningful understanding of that information (Jonassen, D.H, Davidson.M., Collins, M., Campbell,J. & Haag, B.B., 1995). Constructing knowledge is bound to multiple representations of reality (or world), in a particular context and content and has to happen from multiple perspectives. Learning takes place in a social context represented by the cultural background and by collaboration. The student's previous knowledge constructions, beliefs and attitudes are considered in the knowledge construction process.

In more general sense, the students construct their own understanding and knowledge of the world (or reality) through experiencing things and reflecting on those experiences. When we encounter something new, we have to reconcile it with our previous ideas and experience, may be changing what we believe to accommodate new experiences. It recognizes the construction of new understanding as a combination of prior learning, experience, and beliefs an individual student brings to the experience of learning. This understanding is derives from the interaction of an individual student through social context in which learning occurs, by collaboration and from multiple perspectives.

In knowledge construction learning environment students "... *can work together to solve problems, argue about interpretations, negotiate meaning ... Knowledge construction occurs when students explore issue, take positions, discuss positions in an argumentative format, and reflect and evaluate their positions. As a result of contact with new or different perspectives, these activities may contribute to higher levels learning ...*" (Jonassen et al's, 1995).

Knowledge construction is best accomplished through learning as constructive and collaborative activity. *"Constructive approach to learning means personal, active construction of knowledge and learning by doing in an environment with real world problems and authentic materials"* (Liflander Veli-Pekka, 1999). Constructivism principles would appear to satisfy the requirements of the constructive approach to learning. Collaborative learning deals with instructional methods that seek to promote learning through collaborative efforts among students working on a given learning task. Together, constructive and collaborative approach to learning form the term for "collaborative knowledge construction".

2.2 Constructivism

Constructivism is the new theory that is being used for representation of the knowledge construction process (Jonassen, 1994). (Fosnot, 1996) provides a more inclusive definition of constructivism: " *Learning from this perspective is viewed as a self-regulatory process of struggling with the conflict between existing personal models of the world and discrepant new insights, constructing new representation and models of reality as a human meaning-making venture with culturally developed tools and symbols, and further negotiating such meaning through cooperative social activity, discourse, and debate".*

Constructivism has emerged from the work of psychologists and educators such as Piaget and Vygotsky. From the point of view the developmental theories of Piaget and Vygotsky, there are two types of constructivism: cognitive constructivsm and social constructivism (Tudge, J. & Rogoff, B., 1989). Cognitive constructivism believes that knowledge constructions as an individual cognitive process while social constructivism views the process of knowledge construction as tied to the social context. Individual constructions of knowledge are derived from interactions of the students with the social environment. The social environment provides a set of experiences from which the individual tests understanding and adopts group norms (Farquhar, J., 1995). These two standpoints of constructivism are complementary, and represent two sides of an ongoing dynamic process of mutual influences.

2.2.1 Cognitive constructivism

Cognitive constructivism emphasizes the learning as an active process in which students construct new ideas or concepts based upon their previous or current state of understanding. Students confront their understanding in light of what they encounter phenomena that are inconsistent with their constructed knowledge of the world. If what students encounter is inconsistent with their current understandings, their understandings can change to accommodate new experience; conversely, it will be assimilated to adopt new information that fits into prior understandings.

Cognitive constructivism maintains that the mind is instrumental and essential in interpreting events, objects and perspectives on the external world and that these interpretations comprise a knowledge basis that is personal and individualistic (Jonassen, 1991).

While this view focuses on the individual who constructing personally new knowledge, it does not deny the need for social interaction. This further expands to include the idea that we interact with our environments, be they physical or social environments. Besides, it is through social settings that cognitive disturbance typically occurs. For example, through discourse or exchange of ideas with others we come to understand the inconsistencies or inadequacy of our understandings (Kanuka, Heather & Anderson, Terry, 1999). However, even though social interaction is important in learning, in the end the knowledge and skills are constructed at the individual level.

2.2.2 Social constructivism

The social constructivism maintains that new knowledge is created through social interactions. These interactions take place when a group of two or more people engages in dialogue. During this social interaction, individuals are influenced by their prior knowledge and experiences; the cultural context within which the interaction occurs; each individuals own culture and primary language. All of these influences affect the knowledge construction process and the individuals are subjected to negotiation. Through negotiation, each individual must give up a part of their beliefs or perspectives and take from the other individual's beliefs and perspectives. This process results in shared knowledge and understanding that then allows for both individuals to leave the situation changed (Rachel. E. Scott. 2000).

Vygotsky believed that all knowledge starts off social and comes to a cognitive end. This process called Internalization and begins with a social experience. The social experience may be the result after an individual encountered unfamiliar term with which the individual begins to think about and learn the term superficially, such as learning the definition of the term. Ultimately the behavior of the individual will be affected, and the individual will then begin to think with and use the term Vygostky defined externalization as the ability of the individual to go from cognitive back to the social, such as explaining the term to another individual (Rachel. E. Scott. 2000).

Social constructivism generally downplays the mental construction of knowledge and emphasizes the co-construction of knowledge and meaning-making in a social setting. Restated, social constructivism is more concerned with meaning than creating mental structure.

2.3 Collaborative learning

Collaborative learning has a theoretical base in social constructivism (Dewey, J, 1959; Brown, J.S., et al's, 1989; Wiburg, K.M., 1995; Coppola, N., et al's, 1997). (Koschmann, 1996) further describes collaborative learning as a "new paradigm" built upon the viewpoints of social constructivism (Piaget), social cultural theories (Vygotsky), and situated cognition or enculturation. (Koschmann, 1996) also notes several important facets of collaborative learning: "*a commitment through doing, the engagement of students in the cooperative (as opposed to competitive) pursuit knowledge, the transitioning of the instructor's role from authority and chief source of information to facilitator and resource guide*".

(Hiltz, 1995) defined collaborative learning as a process that emphasizes group or cooperative efforts among faculty and students. Collaborative learning stresses active participants and interaction on the part of both students and instructors. Knowledge is viewed as social construct, and therefore the educational process is facilitated by social interaction in an environment that facilitates peer interaction, evaluation, and cooperation (Bouton & Garth, 1983; Bruffee, 1986; Johnson, 1981; Johnson & Johnson, 1975; Whipple, 1987). According to Hiltz, the "teacher" becomes primary a facilitator who structures learning opportunities, serves as resource, and encourages the students to work together to build a common body of knowledge.

The term collaborative learning refers to an instructional method in which students at various performance levels work together in small groups toward a common goal. The students are responsible for one another's learning as well as their own. Thus the success of one student helps other students to be successful (A. Gokhale, 1995).

Collaborative learning is the process whereby each member contributes personal experience, information, perspectives, insight, skills and attitudes with the intent of improving learning accomplishments of others. The group's collective learning ultimately becomes possessed by each individual (W. R. Klemm, 1994).

Proponents of collaborative learning claim that the active exchange of ideas within small groups not only encourages critical thinking but also increases interest among the participants (A. Gokhale, 1995).

According to Vygotsky, students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. Group diversity in terms of knowledge and experience contributes positively to the learning process (A. Gokhale, 1995).

While the above social benefits of collaborative learning appear rather established, however (Salomon, G., 1992) argues that "*groups do not always function well, students collaborate poorly and often little learning takes place… given a reasonable minimum of technological capability, the success or failure of cooperative learning is accurate for by entirely different and far more complex factors…*" (Bannon, 1989) further described, " *It is important to note that the technology per se is usually not the crucial issue, rather the social practices surrounding its use. Simply providing a physical or electronic connection between people does not guarantee that any collaborative learning take place. The important thing is to create a social activity through which learning can occur*".

Researchers have identified a number of factors and conditions necessary for effective collaborative learning. (Dillenbourg & Schneider, 1995) outline the following three categories of conditions: (1) Group composition, the age and levels of participants, the size of the group, and the difference between group members define the group composition factors. (2) Task features, the effects of collaboration vary according to the task. Some tasks prevent the activation of the collaboration mechanisms, while other tasks are appropriated. (3) Communication media, the collaboration mechanisms may only work if the medium chosen for communications is adequate and supported.

(Klemm & Snell, 1995) proposed the following four essentials formalisms for successful collaborative learning method. (1) Individual accountability ("I am responsible for my own learning", (2) Mutual support ("I am responsible for helping you learn too"), (3) Positive interdependence ("To win, we must win together as a team"), and finally (4) Team-building skills ("I will learn how to work as a good team member").

2.4 Collaborative knowledge construction systems

During the last ten years, several technology-based environments of collaborative knowledge construction systems have been created (for example, CLARE, KIE, Web Knowledge Forum, and CoVis). Common to those environments is the provision of tools for the users for collaboratively producing and discussing knowledge. These systems posses the following characteristics:

- Learning is collaborative knowledge construction
- Integration of technology and pedagogy

This section in particular reports on review of the collaborative knowledge construction systems namely, CLARE, KIE, Web Knowledge Forum, and CoVis. The survey is conducted in order to get a good understanding of the systems and to determine these systems according to the theoretical aims they attempt to satisfy. The problem however, is that these systems are not always comparable. This is due to different uses of the computer parallel having different views on collaborative knowledge construction, goals and functions.

The following paragraph is organized into four sections corresponding to four systems namely CLARE, KIE, Web Knowledge Forum and CoVis.

2.4.1 CLARE (Collaborative Learning and Research Environment)

CLARE is a computer supported learning environments that facilitates "meaningful learning" through collaborative knowledge construct. CLARE, which stands for "Collaborative Learning and Research Environment", is a distributed learning environment that provides a semi-formal representation language called RESRA, an explicit process model called SECAI. CLARE is limited to academics, under the domain of *scientific texts understanding.*

RESRA stands for "**RE**presentational **S**chema of **R**esearch **A**rtifacts", is a semi-structured knowledge representation language designed specifically to facilitate collaborative learning from scientific artifact such as research papers. RESRA was designed to support 5 distinct level of collaborative learning namely Summarization, **E**valuation, **C**omparison, **A**rgumentation and **I**ntegration. RESRA defines three distinct types of conceptual constructs: node primitives, link primitives and canonical form. Node primitives represent discrete thematic features of the artifact, for instance claim, concepts, and theory. Node primitives may also explicitly represent the student's viewpoint in terms of critiques, questions, and suggestions. Link primitives describe relationships between thematic features represented by node primitives. For example, in a research paper, a claim is typically made with respect to a particular problem and must be supported by some evidence. In RESRA these relationships are expressed as

"claim $\xrightarrow{\text{respond to}}$ problem" and "evidence $\xrightarrow{\text{support}}$ claims", where responds to and supports are link primitives.

The canonical form characterise typical artifact-level thematic structures as a directed graph of RESRA node and link primitives. Figure 2.1 provides a graphical illustration of RESRA.

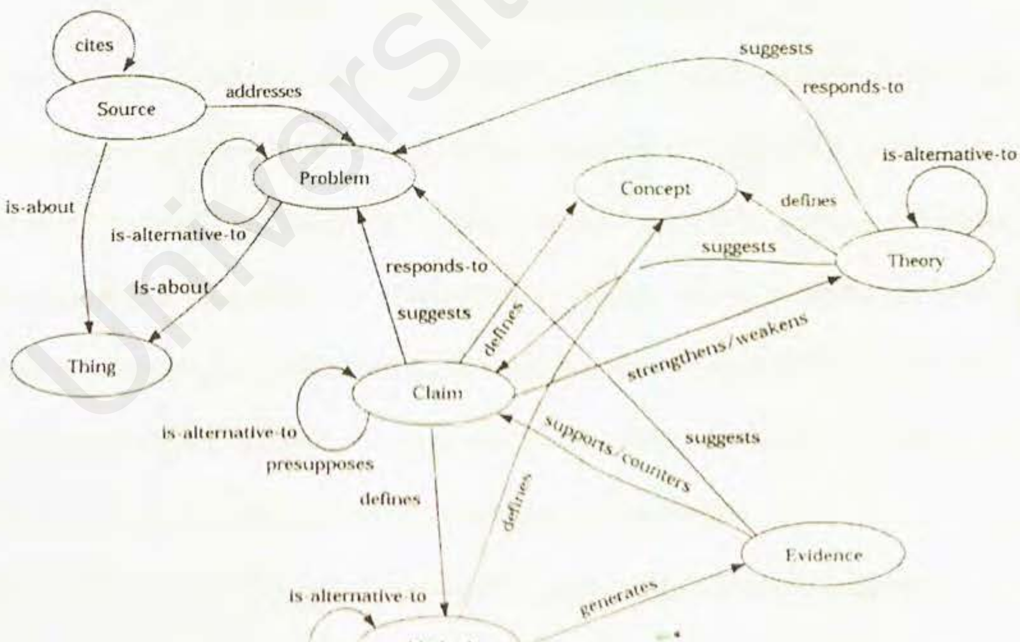

Figure 2.1: Graphical illustration of RESRA.

SECAI stands for "Summarization, Evaluation, Comparison, Argumentation, and Integration", defines an explicit process model for collaborative learning from scientific text. Figure 2.2 shows how these activities are related together to support collaborative knowledge construction.

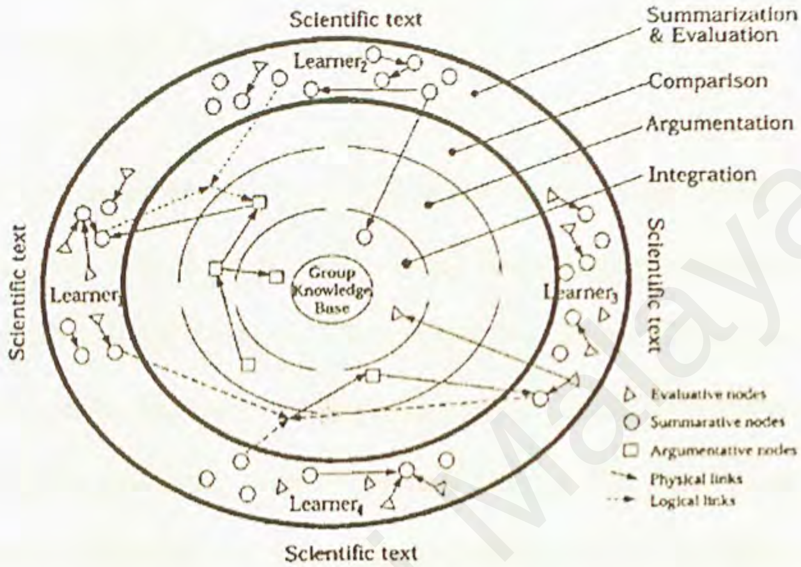

Figure 2.2: SECAI process model

The outermost of concentric circles consists of various types of scientific artifacts and metaphorically, collaborative learning with SECAI process model pulls students from an external, isolated, and individual position inward toward an internal, integrated, and collaborative perspective on the scientific artifact. The first phase of SECAI process is known as exploration which itself consists of two kinds of activities: summarization and evaluation. During this phase, students derive a summary of personal representation of the scientific artifact and evaluation of its content, both expressed in terms of RESRA. This phase is perform privately – students are not allowed to see what others are doing or have done. The second phase is the consolidation process, which consists of three activities: comparison, argumentation, and integration. During comparison, students evaluate the similarities and differences between their representation summary and those of other students. Comparison activities provide a basis for argumentation activities. Both comparison and argumentation activities leads to an improved understanding of the meaning of the artefact. The final step in the consolidation phase is integration, where students create explicit links between their individual representations summary to improve their collective coherence and consistency.

CLARE is grounded on two theoretical tenets: Social constructionism (Berger & Luckman, 1996; K.D. Knorr-Centina, 1981) and assimilation theory of cognitive learning (Ausbel, 1963; Novak & Gowin, 1984). The former affirms the social nature of learning and the imperative of engaging students in the collaborative knowledge construction as apposed to merely information sharing. The latter is centered, around the fundamental assumptions of meaningful learning theory. The theory defines that learning as an ongoing process of relating new knowledge to what the student already knows. The other theoritical foundation for RESRA is the theory of schema in cognitive psychology, which contends that human minds store and retrieve knowledge about the external world in terms of abstract chunks called schemas (Neil Stillings, Mark Feinstein, Jay Garfield, E.L. Rissland, D.D. Rosenbaum, S.E. Wiesler, & L.Baker-Ward, 1987) and that schema plays in an essential role in selection, abstract interpretation and integration of information (J.W. Alba & L. Hasher, 1983).

CLARE has created a tool that supports students in creating summaries individually in semi-structured knowledge representational language called RESRA. RESRA has the following tools:

- An organizational tool that allows incremental, fine-grained representation and integration of scientific artefacts.
- A mapping tool that highlights essential thematic features and relationships within and across scientific text.
- A communication tool and shared frame of reference that highlights similarities and differences between students' points of view
- A tool for learning about the norms and conventions governing formal communication of scientific knowledge.

2.4.2 KIE (Knowledge Integration Environment)

The Knowledge Integration Environment (KIE) combines network resources and software with sound pedagogical principles to improve science learning. KIE networking tools allow students to use scientific evidence in activities that foster knowledge integration. With the KIE, students use evidence from the Internet and tools such as an electronic notebook and on-line discussion tools to make collaborative decisions.

KIE have partly developed their own theoretical framework from empirical studies, Scaffolded Knowledge Integration (SKI), and partly from constructivist research on learning. Another approach that has influenced KIE, is one of looking at cognition as distributed across individuals.

The Scaffolded Knowledge Integration Framework (SKIF) is founded on principals from cognitive psychology, centered around meaningful learning. SKIF (Linn, Songer & Eylon, in press) responds to research showing that science courses confuse students by contradicting "everyday" observations (Carey, 1985; diSessa, 1993; Resnick, 1983; Vosniadou & Brewer, 1992). Rather than changing ideas, students respond to these contradictions by concluding. To support knowledge integration, science courses must help students reconcile scientific models and intuitive observations, and guide students to distinguish technical and colloquial usage of science vocabulary. To gain a robust and predictive understanding of science, the SKIF emphasizes making connections between scientific concepts and relating these concepts to personally relevant situations and problems. The SKIF helps students distinguish and connect their models of the scientific world.

KIE is designed on the basis of the Scaffolded Knowledge Framework, which outlines a framework for integrating scientific understanding into general knowledge (Bell, Davis & Linn). The KIE curriculum consists of activities that ally themselves with the four components of Scaffolded Knowledge Integration Framework (Bell, Davis & Linn):

i. Cognitive goals for science instruction

   Students are encouraged to connect their models of the scientific world (scientific ideas) to personally relevant situations and problem besides engaged in testing, revising, and reformulating scientific ideas.

ii. Making thinking visible

   Emphasizes making alternative models accessible to student, where student benefit the process of comparing scientific explanations, models, or theories. This process takes place when two students debate about theories or when students read a debate between two natural scientists.

iii. Encouraging lifelong learning

Lifelong learning on the part of students as they conduct their investigations and critiques of science.

iv. Providing social support (Linn, 1995)

Social supports during instruction so that student benefit from being actively involved in the classroom setting.

With the KIE, students work collaboratively to answer scientific questions such as "How far does light go?" Students using KIE reflect on their own scientific ideas while considering new evidence from the Internet. Students must examine evidence critically, producing scientific explanations for real world phenomena. They learn how to create their own evidence related to a science topic and to design problem solutions based on scientific principles. Support tools allow students to externalise their ideas and thoughts as well as share those thoughts with others.

KIE provide tools that support collaborative work from the Internet. The KIE software tools consist of several web tools, both commercially available tools and project-developed materials.

Commercial components include:

- World Wide Web Browser provides an appropriate graphical interface for evidence on the Net
- HTML editor, which allows students to create and edit multimedia documents for the web

- E-mail software, which allows students to send and receive electronic mail with other individual

KIE also features the following project-developed software components

- KIE tool palette, a constant interface component that affords navigation of the system components.
- Netbook, a Net-oriented notebook that allows student groups to organize, analyze, and author evidence
- Network Evidence Databases (NED), collections of scientific evidence
- SpeakEasy, a multimedia discussion tool
- Student Knowledge Integration Planner and Profiler (SKIPP), a teacher tool for administrating students activities.
- Knowledge Integration Coach (KIC), which support student feedback during activities.

2.4.3 Web Knowledge Forum

Web Knowledge Forum is a second generation CSILE (Computer Supported Intentional Learning Environments) product designed to promote online communication for collaborative knowledge-building. The basic metaphor is that of a knowledge-building community based on how a scientific community is thought to function. It was named WebCSILE at the beginning and was changed to Web Knowledge Forum. The CSILE approach is based on a substantial body of theory and research concerning how communities of experts build knowledge, which is centred around 3 lines of research (Scardamalia, M., Bereiter, C., McLean, R.S., Swallow, J., & Woodruff, E., 1989; Scardamalia, M. & Bereiter, C, 1994):

i. Intentional learning.

Actively trying to achieve a cognitive goal as distinct from simply trying to do well on school tasks or activities.

ii. The process of expertise

The process aspect of expertise of mental resources that becomes available as a result of pattern learning and automaticity. Expertise can be thought of as process of progressive problem solving and advancement beyond present limits of competence.

iii. Restructuring school as knowledge-building communities

Both intentional learning and the development of expertise require effort and social support.

Extensive research has been done using the original knowledge-building environment. Results of CSILE use in classroom not only verified its effectiveness, but helped shaped subsequent revisions. The current versions, Web Knowledge Forum is the result of this research and of the overriding goal of teaching all students to be knowledge producers.

Web Knowledge Forum is a collaborative database developed for the process of 'Knowledge-building' – defining problems and hypothesizing, researching and collecting information, analyzing and collaborating. In Web Knowledge Forum, students are expected to post questions, define their own learning goals, acquire and build a knowledge base, and collaborate with one another. Built in scaffolds 'cue' students to the thinking strategies that characterise 'expert students' while the structure of the database with its communal views necessitates sharing of information.

Students contribute public notes, build-on to others' ideas and 'reference' the work of peers.

2.4.4 CoVis (Collaborative Visualization)

CoVis provides K-12 students with a learning environment quite different from the usual teaching of well-established facts. Through the use of advanced technologies the project attempts to transform science learning to better resemble the authentic practice of science, that is question-centered, collaborative practice. The project enables high school students to work in collaboration with remote students, teachers, and scientists. The students study atmospheric and environmental sciences through inquiry-based activities. They have access to the same research tools and data sets used by leading-edge scientists, but the tools are specially modified to be appropriate to a learning environment.

The concept of "*communities of practice*" is one of the central theoretical constructs that the CoVis project was designed to explore, and thus it had a strong influence on the pedagogical and technological designs. The CoVis project views the essence of "communities of practice" to be groups of people who share similar goals and interests. In pursuit of these goals and interests, they employ common practices, work with the same tools and express themselves in a common language and through this common activity they come to hold similar beliefs and value systems. In the classroom, this takes the form of what (Collins, A., Brown, J. S., & Newman, S. E., 1989) called cognitive apprenticeship, with students guided both by their teachers and by remote mentors, to think about science as scientists do.

Students conduct an investigation to gain knowledge about some natural phenomena including topics in meteorology and climatology using modified versions of scientific visualization that are appropriate to a learning environment. Students have access to the same research tools and data sets used by real scientists in the field. Students can manipulate data, generate questions, develop plans for identifying and exploring data as well as create artifacts to demonstrate their findings. Throughout the entire process, students can collaborate and communicate with each other and with scientists to share concepts and viewpoints and to post questions.

The CoVis software includes visualization tools for open-ended scientific investigations and communication and collaboration tools for both synchronous and asynchronous collaboration. Visualization tools provide for active, open-ended exploration that characterize constructivist learning and enable students to participate in authentic scientific practice. Asynchronous collaboration is supplied both by conversational communication application like e-mail and newsgroup discussion and by a novel groupware application called collaborative notebook. Collaborative notebook provides mechanisms for recording activities, storing artefacts and sharing the working process with others. Coupled with the scientific visualization tools and other Internet investigations tools provided by the CoVis project, the Collaborative notebook supports the social process of constructing knowledge. Synchronous collaboration is supported both by video conferencing coupled with remote screen sharing.

Table 2.1: Summarises four collaborative knowledge construction systems: CLARE, KIE, Web Knowledge Forum, and CoVis

Table 2.1: Summary Of Four Collaborative Knowledge Construction Systems: CLARE, KIE, Web Knowledge Forum, and CoVis

	CLARE	KIE	Web Knowledge Forum	CoVis
Domain	Scientific text understanding	Knowledge integration of science learning	Scientific knowledge-building community	Scientific community of practice
Theories	1. Social constructionism 2. Assimilation theory of cognitive learning 3. The theory of schema in cognitive psychology	KIE have partly developed their own theoretical framework from empirical studies, Scaffolded Knowledge Integration (SKI), and partly from constructivist research on learning. Another approach that has influenced KIE, is one of looking at cognition as distributed across individuals.	1. Intentional learning 2. The process of expertise 3. Restructuring school as knowledge building communities	1. Cognitive apprenticeship
Process model	SECAI process model	-	-	-
Assumptions about collaborative knowledge construction	The best way to construct knowledge is to collaboratively produce a summary through collaborative processes supported by the SECAI process model. SECAI process model specifically controls the process of collaborative learning from *scientific text understandings*.	The KIE project argues that the best way to construct knowledge is to have a software environment that supports collaborative learning from Internet. Besides, the four components of SKIF help students to develop the ability to examine evidence critically, an inclination toward knowledge integration. To accomplish this, KIE relies on the Internet as a resource for evidence. Students are encouraged to gather information supporting different theoretical models. They then critically examine the evidence to determine which model is valid.	It takes as its basic metaphor a community of scientists who learn and advance for constructing knowledge in social milieu. By interacting with each other, providing both challenge and support, scientists help raise the whole community's knowledge. They start where each member is, but through dialogue, help, questioning, they help each other think through their position and reach new heights of knowledge.	CoVis argues that active learning can be further enhance through social cultural commitment, communication and collaboration throughout the knowledge construction process. The act of communication during learning can enhance the quality of the learning. Communication is more than simply passing static knowledge back and forth between participants. The act of communication transforms the entire partner involved (Pea, 1994). In addition to this assumption, CoVis beliefs that an important goal of learning is to gain entrance to or understanding of communities of practice.

(continue...)	CLARE	KIE	Web Knowledge Forum	CoVis
Tools	CLARE has created a tool that supports students in creating summaries individually in semi-structured knowledge representational language called RESRA. RESRA has the following tools: 1. An organizational tool 2. A mapping tool 3. A communication tool and shared frame 4. A tool for learning about the norms and conventions governing formal communication of scientific knowledge.	Commercial components (e.g. web browser, HTML editor, Email) and project-developed software components (e.g. KIE Tool palette, Netbook, NED, Speak Easy, SKIPP, and KIC).	Collaborative database	Visualization tools for open-ended scientific investigations and communication and collaboration tools for both synchronous and asynchronous collaboration.
Learning activities	CLARE has created a tool that supports the students in creating summaries of scientific artefacts in a collaborative way. First, each student creates his or her own summary individually in RESRA. Then the summaries are compared, evaluate and discussions arise. The summary are then integrated to a common summary through a collaborative process.	The KIE involves students in projects in which they work with scientific questions such as "How far does light go?" They work with scientific evidence from the Internet and structure it and compare and integrate it with others.	Students start with an empty database to which they create notes that express their ideas or theories and enter them into a database. They then read and build on each other's notes, add links among related ideas, reorganize the knowledge, collaborate with peers as they acquire and build a knowledge base and ultimately "rise-above" to new understandings. Ideas can be revisited, critiqued, and organized in a variety of ways allowing them to view the collaborative database from many perspectives.	Participating students study atmospheric and environmental sciences through inquiry-based activities. Using modified versions of scientific visualization software, students have access to the same research tools and data sets used by leading-edge scientists in the field. Students can access and manipulate data, generate questions, develop plans for identifying and exploring data as well as create artifacts to demonstrate their findings. Throughout the entire process, students can collaborate and communicate with each other and with scientists to share concepts and viewpoints and to pose questions.

2.5 Collaborative knowledge construction process model

Table 2.1 has shown that only CLARE provides an explicit process model named SECAI that specifically controls the process of collaborative learning from *scientific text understandings*. KIE on the contrary has developed the curriculum activities that foster knowledge integration. However, Web Knowledge Forum and CoVis argue that the availability of tools in a computational environment is enough to motivate or to induce collaborative knowledge construction. (Wan, 1994) contends that software systems must provide users with structural and process-level guidance on how to collaboratively construct knowledge. Countless hours of searching the journals, conference papers and Internet revealed that not many process models for collaborative knowledge construction are being developed. Stahl's collaborative knowledge-building model is the only generic process model available to date, which provides structured process-level that foster collaborative knowledge construction. The following paragraph particularly describes Stahl's collaborative knowledge-building model in detail.

2.5.1 Stahl's collaborative knowledge-building model

Stahl's model has been formulated in the year 2000. (Stahl, 2000) describes a model of collaborative knowledge-building corresponding to multiple distinguishable phases that constitute a cycle of personal and social knowledge. Stahl also outlines as to how the computer can be used to scaffold every phases of the knowledge-building process. Figure 2.3 shows the Stahl's model. The arrows represent transformation processes while rectangles represent the product of these processes.

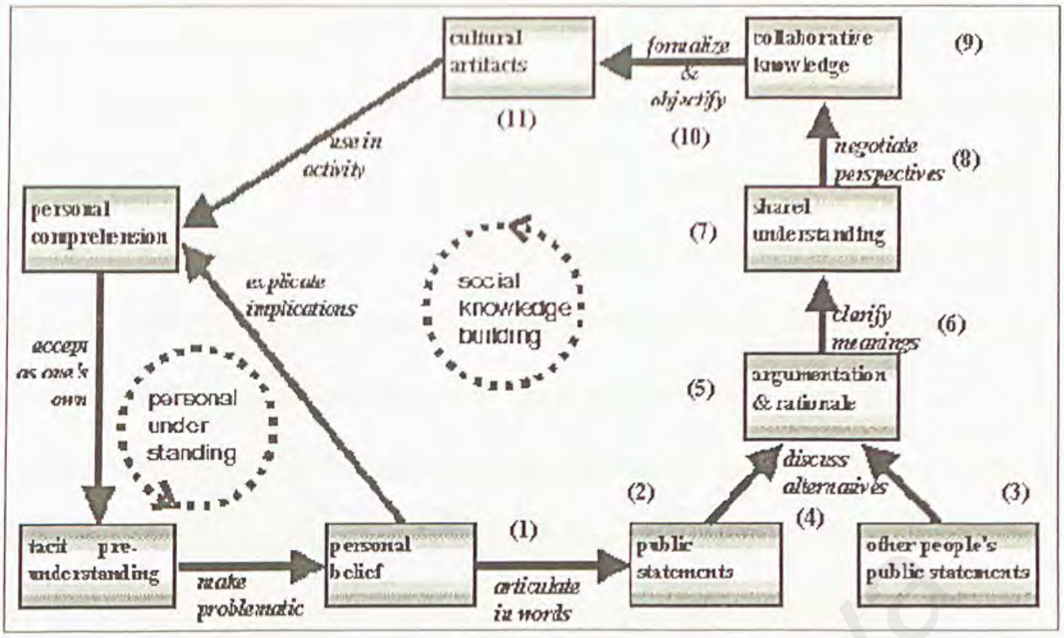

Figure 2.3: Stahl's model

In the first phase, the computer can be used to articulate personal belief into statement. This can be done with a text editor or simple word processor. In second and third phase, the public statements by one person who articulate his/her personal belief in words confront those of other people's public statements. Computational representation of perspectives can be used to represent these from various individual and allows for easy comparison of them. The forth phase concerns the discovery of discrepancy among ideas or perspectives. In this phase, the students exchange opinions, ask questions and discuss their perspectives among themselves. The discussion forum is a minimal instance of this. Fifth, the computer can be used to structure the discussion and formalized it in a representation of the argumentation graph. During the sixth and seventh phase, the students further clarify the meaning of important term used in various competing claims. This leads to a shared understanding thus forming a group glossary. Computer support can be used to represent the glossary discussion. In the eighth phase, the students are negotiating or constructing knowledge and try to compromise among themselves. This can be done with a computer support of negotiation. The tenth phase concerns formalize and objectify of this new knowledge. While it must have already been expressed explicitly at least in written language, it can now be presented in another symbolic form, for instance, conference presentations, journals, article and books. This leads to the final phase in which the representations of the new shared knowledge in publications and other cultural artifacts are themselves accepted as part of the established paradigm. In every step of the process, there is an important knowledge created for the future process of social knowledge-building. Stahl maintains that unlike traditional storage of discussions like chatrooms or newsgroups, the process at every step should be captured, stored and made available to all future users of the system.

In summary, Stahl's model of model serves as a generic model for the design of collaborative knowledge construction learning environment and can be used as a basis for providing computer support tools to complete the collaborative knowledge construction loop. In contrast, any computer support tools under the domain of *scientific texts understanding* could possibly be built based on SECAI conceptual model. Stahl's model so therefore is the main focus for this research.

2.6 Summary of the phases of Stahl's model against the collaborative knowledge construction systems: CLARE, KIE, Web Knowledge Forum, and CoVis.

This section summarizes the phases of Stahl's model against the collaborative knowledge construction systems: CLARE, KIE, Web Knowledge Forum, and CoVis.

The purpose of this section is to determine:

1. The applicability of Stahl's model to existing collaborative knowledge construction systems: CLARE, KIE, Web Knowledge Forum, and CoVis.
2. The extent to which Stahl's model foster collaborative knowledge construction

CLARE

In CLARE, students use the mapping tool to derive a summary of personal representation of the scientific artifact, expressed in RESRA. In the next stage, using the communication tool and the shared frame of reference tool students evaluate the similarities and differences between their representations and those of other students. Comparison activities provide a basis for argumentation. Students argue with one another over representation, which leads to an improved understanding of the meaning of the artifact. Importantly, it reveals other students' perspectives on the artifact. Finally, the formalization of the understandings is integrated, where students create explicit links between their individual representations to improve their collective coherence and consistency. The use of organizational tool allows for incremental, fine-grained representation and integration of scientific artefacts. In addition, CLARE provides the tool for learning about the norms and conventions governing formal communication of scientific knowledge.

KIE

As part of the KIE pilot study, students engaged in the "How far does light go?" Students begin the activity by stating their personal position on how far light goes. Then they review evidence on the Internet using the web browser tool and determine whether each piece supports, contradicts, or is irrelevant to their position. Students next engage in a brainstorming activity to create pieces of evidence using the Netbook tool to bolster their argument by pulling from experiences in their own lives. Using the HTML editor tool, students can make the evidence they create available to all class members over the Internet. In addition, the SpeakEasy tool allows students to conduct structured conversations about their scientific ideas over the Internet. The students then synthesize the evidence and formulate a scientific argument. The NED tool facilitates the students to collect scientific evidence, organized by topic and activity. Next, the team of students present their arguments in a classroom discussion and respond to questions from the other students and the teacher. Finally, the team of students reflect upon issues that came up during the activity and once again state their position on how far light goes. The KIC tool is an online guidance system, which provides supporting prompts and feedback as students work on their activities.

Web Knowledge Forum

Web Knowledge Forum provides HTML editor that allows articulation of public statements to represent their ideas. Students may contribute public notes and build-on to others 'ideas' to indicate their rationale or perspectives. The ongoing practice of knowledge constructions process helps students to clarify the meanings and come to a shared understanding. There is little evidence that students argue with one another over the production of shared knowledge although they help one another in the process to converge on a shared understanding. The formalization of the understanding are manifested as communal views and stored permanently on the 'collaborative database' for all to see. Of particular importance is the 'collaborative database' to which students submit ideas, share information and post public notes.

CoVis

In CoVis, students use the email and newsgroup to make public statement and also listen to others statements. Students create artifacts based on their personal understanding, which are also their personal statements. Using the CoVis visualiser, students had the opportunity to create their own artifacts to generate and demonstrate findings. Both the visualisation process and the visualization themselves become the topic of a scientific dialogue. For example, students conduct an investigation to gain new knowledge about some natural phenomena, for example weather predictions. Students use the weather visualiser to create weather maps and satellite images of the current weather. Working from this visualization, they attempted to project forward forty-eight hours using their limited understanding of meteorology to make predictions. Their predictions could be expressed in the form of weather maps that they drew themselves. Once students groups had entered their predictions, and the rationale for them, they were able to view the predictions of the other groups and to argue for or against competing forecasts. Together they come to a shared understanding of a scientific concepts formalized this and created a private journal or a shared project notebook as a cultural artifact. The final product was then integrated with their personal comprehension of the practice of science and hopefully to be used in another collaborative knowledge construction process later.

Table 2.2 summarizes phases of Stahl's model against the collaborative knowledge construction system: CLARE, KIE, Knowledge Forum and CoVis

Table 2.2: Summary of the phases of Stahl's model against the collaborative knowledge construction systems

	PHASE OF STAHL'S MODEL	CLARE	KIE	WEB KNOWLEDGE FORUM	COVIS
1	Articulate in words	✓	✓	✓	✓
2	Public statements	✓	✓	✓	✓
3	Other people's public statements	✓	✓	✓	✓
4	Discussed alternatives	✓	✓		✓
5	Argumentation and rationale	✓	✓		✓
6	Clarify meanings	✓		✓	✓
7	Shared understanding	✓		✓	✓
8	Negotiate perspectives				
9	Collaborative knowledge				
10	Formalize and objectify	✓	✓	✓	✓
11	Cultural artifacts and representations			✓	✓

Table 2.2 shows that Stahl's model is largely applicable to many collaborative knowledge construction learning environments today although most do not provide tools to support all phases of collaborative knowledge construction process. Stahl's model is simply appropriate process model available to date that foster collaborative knowledge construction. Table 2.2 also shows that CLARE and KIE fail to provide support for closing collaborative knowledge construction loop focusing as much on ending up with one collaborative piece of work. The important steps in the social knowledge construction process must be completed to produce learning (Stahl, 2000). Besides, these systems fail to provide explicit mechanisms for capturing knowledge at the different stages in the collaborative knowledge construction process. Stahl maintains that each step of the process has knowledge, which should be captured, stored and available to all future users (Stahl, 2000). In light of the above survey, it is decided to augment collaborative knowledge construction learning environment to provide complete range of tools per Stahl's loop as well as to provide mechanisms for capturing knowledge for each of these stages.

2.7 Summary

Chapter 2 reviewed on learning theories that particularly relevant to the design of collaborative knowledge construction learning environment. It also reviewed the major collaborative knowledge construction systems and models. The synthesized findings of the reviewed literature then form the crux of the research approach:

1. A process model to guide students through the collaborative knowledge construction process.
2. A collaborative knowledge construction learning environment to support the process model.

The detail descriptions of each component are pointed out in Chapter 3. In the next chapter, Stahl's generic model is used as a basis for formulating the proposed process model, named COKC.

Chapter 3

COKC and KC-Space

Chapter 3 presents the detailed description of the COKC process model. The COKC process model presented provides a framework for the design and development of a collaborative knowledge construction learning environment called the KC-Space. This chapter also describes the usage scenario for working with the KC-Space. Chapter 3 concludes with a comparison discussion of KC-Space with other collaborative knowledge construction systems.

3.1 The design process model

The process model is founded on three main theories of learning namely cognitive constructivism, social constructivism, and collaborative learning. Cognitive constructivism is promoted by presenting students with tools to help them express beliefs, presents what they know to others and reflect upon them, interpret and organize their personal knowledge throughout collaborative knowledge construction process. Contrary, social constructivism is encouraged by providing convenient medium for social process of interaction with ideas from multiple perspectives, presenting students with ways to argue and critique each other's perspective, facilitating exchange of ideas through extensive discussion, clarifying any disagreement and approaching consensus through social negotiation of meaning. The cognitive constructivism and social constructivism principles are based on the same assumptions as collaborative learning. Collaborative learning is supported by collaborative and communicative tools, which encourage group discussions and knowledge sharing. Specifically, the design process model is formulated based on Stahl's generic model of collaborative knowledge-building. Stahl's model is rather a complex process to study and support, thus there are significant difficulties in implementing and successfully deploying computer supports as per Stahl's knowledge-building theory. Instead, based on the analysis of Stahl's theory, the interpretation of the approach to phases of collaborative knowledge construction is concluded and the computer support tools to scaffold each of the phases is then scrutinised. Table 3.1 summarises the analysis of Stahl's model, which satisfies the characteristics exhibited by three main theories of learning: cognitive constructivism, social constructivism, and collaborative learning. Together they present the basis for the design process model, named COKC. The detail descriptions of the tools are pointed out in section 3.3.

Table 3.1: Analysis summaries of Stahl's model

PROPOSED PHASES	COGNITIVE CONSTRUCTIVISM	SOCIAL CONSTRUCTIVISM	COLLABORATIVE LEARNING	PROPOSED TOOLS
Articulation	Individual students articulate their ideas to a topic or issue into personal perspectives		Prepares students for collaboration	Personal notebook, Articulation editor
Comparison		Provide a basis for argumentation	Students explore and compare their personal perspectives with those of others	Comparator
Argumentation		Promote collaborative exchange of ideas	Students take part in argumentation discussion by responding to critics of each other ideas	Argumentation discussion map
Clarification		Lead to shared understanding of the meaning of the issue under discussion	Clarification of the meaning of terms	Clarification discussion map
Negotiation		Shared knowledge constructed	Co-construction of each other's perspective or generates solution to reach consensus.	Negotiation discussion map
Integration	The establishment of group perspectives provides a basis for individual students to build on this knowledge within their own perspectives	Learning outcomes in term of group perspectives	Relating, aggregating and abstracting negotiated shared knowledge into a structured, well-integrated group perspectives	Integration discussion map, Reflective editor

3.2 COKC (Collaborative Knowledge Construction) process model

The COKC process model enables students to articulate ideas, to compare them with others, to argue and critique each other's perspective, to clarify any disagreement or misunderstanding, to negotiate and to integrate other people's ideas with their own. To achieve these goals, COKC process model defines six phases of collaborative knowledge construction process, namely Articulation, Comparison, Argumentation, Clarification, Negotiation and Integration as shown in Figure 3.1. Each phase of the COKC process model provides specific collaborative tools to assist students with their activities. The COKC process model and the proposed tools will become the basis for the development of a collaborative knowledge construction learning environment, named KC-Space. The detail descriptions of the KC-Space are pointed out later in section 3.3

The COKC process model integrates individual and multiple distinguishable social aspects of collaborative knowledge construction process. Individual constructions of knowledge are derived from interactions of the students with the social environment. The individual experience, current mental structures and belief will directly influence the way that the student will 'construct' his or her new knowledge. The idea is that, personal belief is formulated and articulated in words and this perspective is then taken up in a social setting that may lead through collaborative discourse toward shared knowledge. The result of social process is a group perspective hence group knowledge. Group knowledge then form a basis for individual student to build on this newly constructed knowledge within their own perspectives consequently enters into one's personal understanding thus shaping it with ways of thinking. Figure 3.1 depicts the COKC process model.

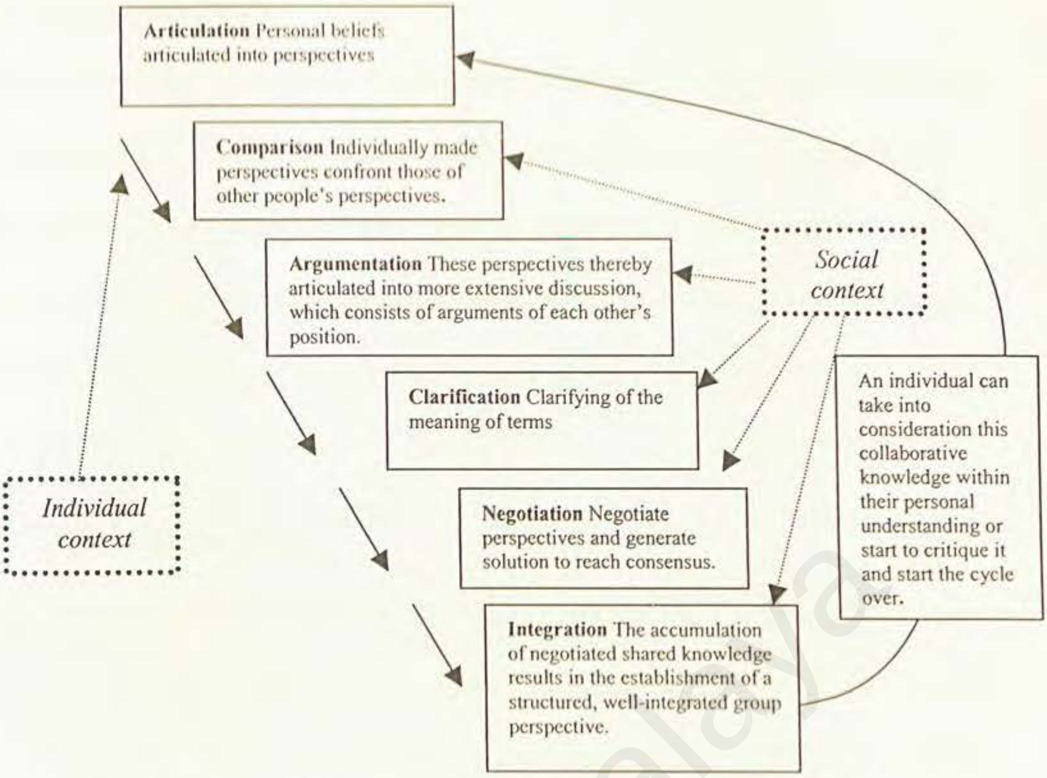

Figure 3.1: Graphical representation of COKC process model

Sections 3.2.1 – 3.2.6 provides a brief description of each phase and the specific collaborative tools, which assist students with the activities.

3.2.1 Articulation Phase

Articulation phase is performed individually and independently. An essential cognitive mechanism of this phase is the articulation process, which is made possible by individual students who construct their deeply rooted beliefs and conceptions of a particular issue. Over time, their ideas about what "issue" means become part of the common knowledge through social interaction, discussion, and negotiation.

3.2.2 Comparison Phase

Students proceed in the manner of comparing their individually made perspectives. By comparing their differed perspectives, one can discern the similarities and differences in viewpoint held by individual students, the process of which, particular conceptual perspectives of the group of students are made visible, which in turn which lead to conflicts, and issues that need to be discussed.

3.2.3 Argumentation Phase

Students take part in an argumentation process by responding to critics of each other's position either by arguments to-support or arguments to-object position. Argumentation in the decision-making process shape individual cognitive development and encourage collaborative exchange of ideas.

3.2.4 Clarification Phase

The establishment of shared understanding is one of the significant requirements for collaborative knowledge construction. This can be achieved by elucidating the discrepancies in interpretation and terminologies in various competing claims and positions. The clarification of discussion can be made explicit by how individual students understand the terms they use. Perhaps as importantly it reveals how other students' interpretation of issue under discussion differs. The discussion results in group glossary of the agreed upon definition of important terms and leads to an improved understanding of the meaning of the issue being discussed.

3.2.5 Negotiation Phase

The most delicate stage of collaborative knowledge construction is negotiation. Negotiation is of fundamental importance in helping multiple perspectives to converge on shared knowledge. Students share a focus on the same issue and negotiate on one another's perspectives. On the event of any incomplete, disagreeing, opposed or disbelieved perspectives, the students clarify these perspectives and critically evaluate (its strength and its relevance) until a common answer, solution or conceptual understanding arises. It is crucial for this stage of learning that tasks require discussion and contribution from all group members. If the negotiation of the diverse perspectives manages to achieve a common consensus, then such a result is accepted as knowledge.

3.2.6 Integration Phase

The final phase of the collaborative knowledge construction process requires explicit mechanisms of knowledge integration. In this process, the accumulation and integration of negotiated shared knowledge results in the establishment of a group perspective of the same construct. Students collaboratively create article that reflects the group's integrated view and ultimately integrate them into a coherent whole thus ending up with one collaborative piece of work.

3.3 KC-Space (Knowledge Construction Space) learning environment

Knowledge Construction Space aims to provide a workspace for students to articulate their ideas, to discuss ideas with others, to differentiate their own perspectives and adopt ideas those of other people, clarify disagreement, negotiate mutual understandings and formulate knowledge into tangible group product. Knowledge Construction Space provides the following functions:

- Facilitates the process of articulating ideas and provides an entry and storage location for students throughout the collaborative knowledge construction process.
- Providing the ability to view and contrast alternative perspectives and adapt ideas from a group of students.
- Supporting explicit representation of discussions and thread, which allow individual differences and similarities in viewpoint to be highlighted, compared, and contrasted.
- Providing the facility like construction of a group glossary and searchable group glossary.
- Providing extensive support for collecting, revising, organizing, and relating ideas as part of the collaborative knowledge construction.
- Providing access to shared repository as well as supporting students working in small groups to construct articles to be shared with others

3.3.1 Personal Notebook

The Personal Notebook facilitates the process of articulating ideas and provides an entry and storage location for students throughout the collaborative knowledge construction process.

Students can note their responses, expand and edit what they had written earlier in a plain text or HTML format. The HTML option enables students to include links to Internet sites, display images or format their messages (fonts, colours) using conventional html tags. Students can also make multiple copies or links (virtual copies) from notes in a shared repository to their notebook. Besides, students are able to include additional documents such as links to other resources on the WWW or record graphic, sound, video and animation within their notebooks.

The Personal Notebook has a fairly strong search function which accepts a search strings that matches and allows for the bringing together of notes of interest to the searcher. Moreover, the notebook has the best features for uploading files of arbitrary type (Word, Rich Text Format).

3.3.2 Articulation Editor

The Articulation Editor facilitates students to post their perspective of a given issue by composing notes in HTML format. Students may include links in their notes that refer to hypertext information on the Internet or images and sounds files to their notes.

3.3.3 Comparator

Comparator contains threaded notes of students' perspectives from a shared repository. The space provides ability to view and contrast others contribution of perspectives held by the group of students.

3.3.4 Argumentation Discussion Map

The Argumentation Discussion Map allows explicit representation of discussions and threads, which allow students to reflect and compare alternate viewpoints and its associated arguments.

The map uses the concepts of issues, positions, arguments, elaborations, questions and answers to organize the argumentation discourse. The argumentation structure provides a view on the messages that substantially facilitates the retrieval of contributions to the discussion. The Argumentation Discussion Map is a computational representation of a 'tree' of divergent opinion, which evolves from user interactions during argumentation phase of collaborative knowledge construction process. The 'tree' shows the relationship between the response and the origin of thread. Users can respond to an existing thread by retrieving contributions submitted by other parties and add their positions and arguments. These contributions may include additional documents such as links to other resources on the WWW, images, and sounds files. The thread thus appears within the 'tree' structure and descendents of any node are responses to that thread.

Table 3.2: A summary of argumentation discussion map node type

NODE TYPE	DESCRIPTION	ASSOCIATED SYMBOL
Issue	Each issue can have many Positions	
Position	One could place their position of a particular issue which in turn is substantial in an argument to support or object	
Agreement	Argument to-support	
Disagreement	Argument to-object	
Elaboration	Respond to an existing comment where some evidence is described	
Question	Contribute question to a comment made	
Answer	Answer to a question that are raised	

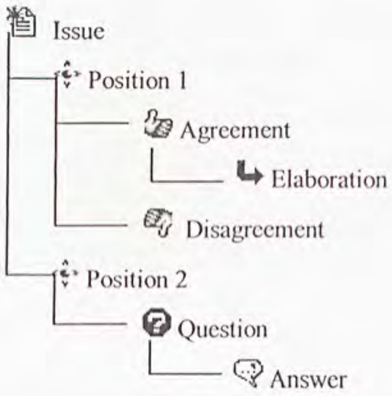

Figure 3.2: Graphical representation of typical argumentation discussion map

3.3.5 Clarification Discussion Map

The Clarification Discussion Map provides an easy way for a group to communicate and compare their alternate terminologies and its associated meaning during the process of constructing glossary. The Clarification Discussion Map structure can be made explicit in a representation of graphical map. See table 3.3 for the summary of Clarification Discussion Map node type. Students can respond to term posted by one another, argue for or against another, provide citation to an existing term or perhaps negotiate the term used by clarifying the differences in interpretation and terminologies of various competing claims and positions.

The Group Glossary is a collection of agreed upon definition of important term that has been constructed for use as part of collaborative knowledge construction process. The Group Glossary provides facilities like searchable Group Glossary of the group knowledge contents.

Table 3.3: A summary of clarification discussion map node type

NODE TYPE	DESCRIPTION	ASSOCIATED SYMBOL
Term	Terminologies	
Quote	Provide citation to an existing term	
Agreement	Argument to-support	
Disagreement	Argument to-object	
Claimed definition	Claimed definition of term in various competing claims and position	
Decision	Locked term	
Question	Contribute question to a comment made	
Answer	Answer to a question that are raised	

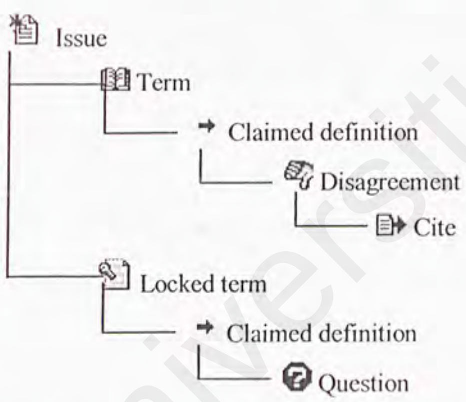

Figure 3.3: Graphical representation of typical clarification discussion map

3.3.6 Negotiation Discussion Map

Negotiation Discussion Map provides extensive support for revising and organizing 'Argumentation Discussion Notes' as part of the negotiation process. It allows students to:

1. Summarise, annotate, and rephrase 'Argumentation Discussion Notes' as part of the negotiation process.
2. Read the 'Knowledge Negotiation Note' and rate it strength and relevance along specific measurement (high, medium, or low).
3. Negotiate with group members to determine pieces of notes that should be accepted and promoted to represent their collaborative product.

Table 3.4: A summary of negotiation discussion map node type

NODE TYPE	DESCRIPTION	ASSOCIATED SYMBOL
Issue	Issue	
Knowledge Negotiation Note	Contribute Knowledge Negotiation Note	
Agreement	Argument to-support	
Disagreement	Argument to-object	
Elaboration	Respond to an existing comment where some evidence is described	
Question	Contribute question to a comment made	
Answer	Answer to a question that are raised	

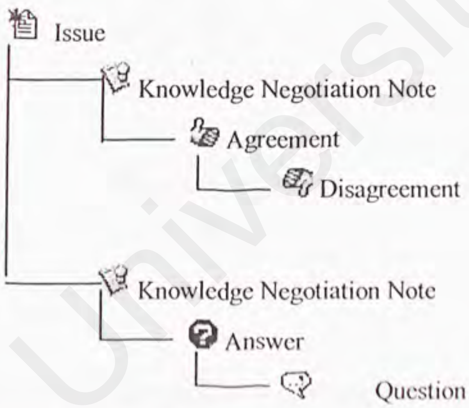

Figure 3.4: Graphical representation of typical negotiation discussion map

3.3.7 Integration Discussion Map

The Integration Discussion Map facilitates students working collaboratively in small groups to create article that reflects the group's integrated view of the knowledge construct.

Table 3.5: A summary of integration discussion map node type

NODE TYPE	DESCRIPTION	ASSOCIATED SYMBOL
Issue	Issue	
Contribution of element	Contribute element for group reflective article	
Agreement	Argument to-support	
Disagreement	Argument to-object	
Elaboration	Respond to an existing comment where some evidence is described	
Question	Contribute question to a comment made	
Answer	Answer to a question that are raised	

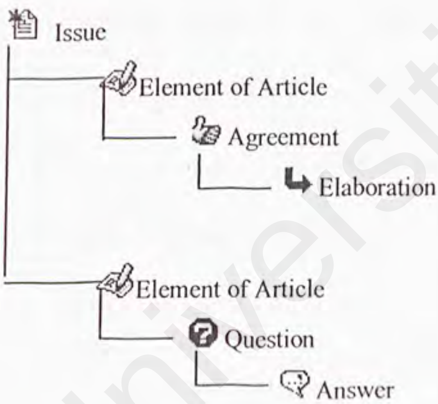

Figure 3.5: Graphical representation of typical integration discussion map

3.3.8 Reflective Editor

The reflective editor provides the ability to retrieve the group contribution of elements of the article, edit, and add graphics to the group reflective article.

3.4 KC-Space usage scenarios

Figure 3.6 presents the usage scenarios for working with the KC-Space. It consists of two spaces of which the Private Space and the Shared Space.

1. The private space of individual context contains private notes, personal annotations, and provides an entry and storage location for students throughout the collaborative knowledge construction process.
2. The shared space of social context provides group discussion such as clarification discussion and negotiation discussion.

The diagram also presents six important phases of collaborative knowledge construction process, namely Articulation phase, Comparison phase, Argumentation phase, Clarification phase, Negotiation phase and Integration phase. The convention in the diagram is that the block arrow ↷ represents the transition processes corresponding to activities involved in an individual context. The line arrow → represents the transition processes from Articulation phase of individual context through various phases in social context: Comparison phase, Argumentation phase, Clarification phase, Negotiation phase and Integration phase.

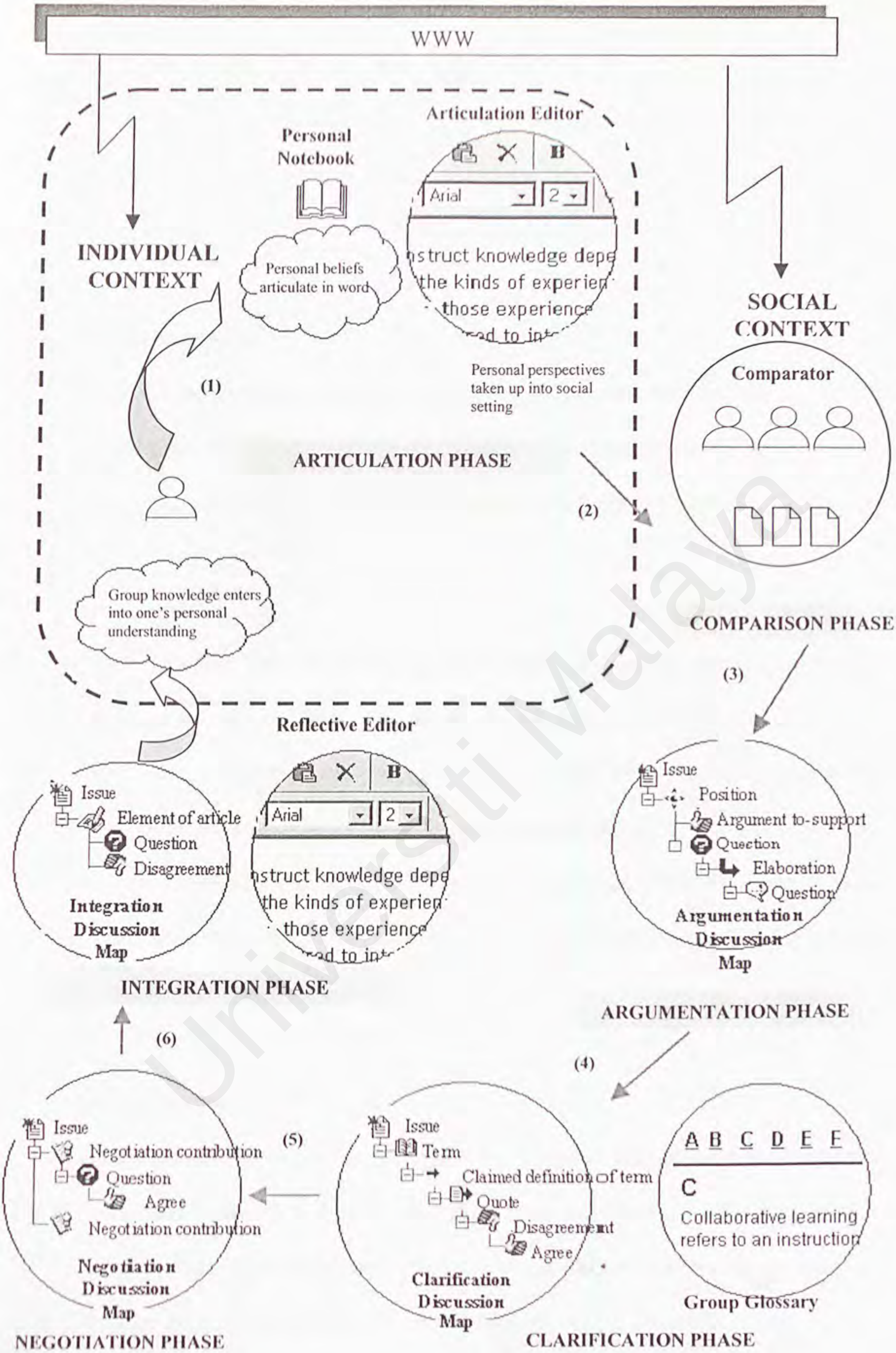

Figure 3.6: Graphical representation of KC-Space usage scenarios

Articulation phase

Firstly, the articulation editor tool and personal notebook tool can be used to articulate personal beliefs into personal perspective. This perspective is then taken up into a social setting.

Comparison phase

Secondly, the individual made perspective is then compared with other students' perspectives. This phase involve the discovery of discrepancy among ideas and perspectives. The comparator tool can be used to accomplish this task.

Argumentation phase

Thirdly, students take part in an argumentation discussion. The argumentation discussion map tool can be used to capture the discussion allowing students to see all the different perspectives and respond to critics either by arguments to-support or argument to-object position. During the argumentation phase, the students exchange ideas, ask and answer questions, and provide description about the topic of their discussion. Besides, this phase concerns the discovery of different terminologies used in various competing claims and positions.

Clarification phase

Fourth, students take part in clarification process dealing with different terminologies of the same construct to further clarify the topic of discussion. The clarification process produced a group glossary of agreed upon definition of term. The clarification discussion map tool can be used to achieve this task.

Negotiation phase

Fifth, students collaboratively figure out the topic of discussion, negotiate perspectives and generate solution to reach consensus thus forming a negotiated shared knowledge. The negotiation discussion map tool can be used to capture the negotiation discussion.

Integration phase

Sixth, the accumulation and integration of negotiated shared knowledge result in the establishment of group perspective of the same construct hence group knowledge. During this phase, students collaboratively create article, which reflects the group integrated view. This can be done with the integration discussion map tool and the use of reflective editor tool

The product of integration phase form a basis for individual student to build on this group knowledge within their own perspectives and consequently enters into their personal understanding thus shaping it with their ways of thinking.

3.5 Comparison of KC-Space with other collaborative knowledge construction systems

Firstly, this section describes KC-Space as it applies to Stahl's model in completion (see Chapter 2, section 2.5). Next it concludes with a discussion of the comparison between KC-Space with other collaborative knowledge construction systems as described in Chapter 2, section 2.6.

KC-Space

First, the articulation editor tool and personal notebook tool can be used to accomplish the generation of one's perspectives. Second, students compare perspectives and adopt others ideas. The comparator tool can be used to accomplish this task. Third, students take these ideas and 'argue' back and forth on the issue being investigated. This process can be captured by some kind of argumentation visualization tool that is the argumentation discussion map tool. Forth, students come to a shared understanding and create a group glossary. This can be done with the clarification discussion map tool. The tool provides an easy way for students to communicate and compare the various terminologies and its associated meaning in the process of constructing group glossary. The fifth phase leads to negotiation. The computer can be used to map the negotiation discussion. The negotiation discussion map tool provides extensive support for students to collaboratively figure out the issues, negotiate perspectives and generate solution to reach consensus. Lastly, the knowledge is consolidated (through the integration discussion map tool and use of reflective editor tool) into a cultural artifact. The tool enables students to collaboratively create article, which reflects the group integrated view.

Table 3.6 includes KC-Space within the listed phases of Stahl's model.

Table 3.6: Comparison of KC-Space with other collaborative knowledge construction systems

	PHASE OF STAHL'S MODEL	CLARE	KIE	WEB KNOWLEDGE FORUM	COVIS	KC-SPACE
1	Articulate in words	✓	✓	✓	✓	✓
2	Public statements	✓	✓	✓	✓	✓
3	Other people's public statements	✓	✓	✓	✓	✓
4	Discussed alternatives	✓	✓		✓	✓
5	Argumentation and rationale	✓	✓		✓	✓
6	Clarify meanings	✓		✓	✓	✓
7	Shared understanding	✓		✓	✓	✓
8	Negotiate perspectives					✓
9	Collaborative knowledge					✓
10	Formalize and objectify	✓	✓	✓	✓	✓
11	Cultural artifacts and representations			✓	✓	✓

In conclusion, it is clear that KC-Space outperformed the existing collaborative knowledge construction systems. It is clear that KC-Space has covered all the important phases per Stahl's theory and provides complete range of tools for closing the collaborative knowledge construction loop focusing as much on ending up with one collaborative piece of work. Besides, KC-Space has provides explicit mechanisms for capturing knowledge at the different stages in the collaborative knowledge construction process.

3.6 Summary

This chapter discusses the COKC process model in support of collaborative knowledge construction process. COKC process model enable students to construct and integrate their knowledge through both individual and social context. Specific collaborative tools for each phase of COKC process model are identified to assist students in the collaborative knowledge construction activities. The COKC process model presented provides a framework for the design and development of a collaborative knowledge construction learning environment called the KC-Space. Then, this chapter provides the description of the KC-Space that integrates the COKC process model. The usage scenario for working with the KC-Space is presented next. This chapter concludes with a comparison discussion of KC-Space with other collaborative knowledge construction systems.

Chapter 4

KC-Space Analysis and Design

This chapter presents the analysis and design of KC-Space. In the analysis section, both the functional and non-functional requirements are identified. The object-oriented analysis is also addressed. In the design section, the architecture of KC-Space, and object-oriented design are presented.

4.1 KC-Space analysis

4.1.1 Requirement analysis

There are two main concerns for KC-Space requirements: functional and non-functional requirements. Functional requirements describe the functionality of KC-Space along the proposed model. Whereas non-functional requirements describe other aspects of usability, efficiency and other run time properties.

KC-Space functional requirements

The functional requirements are stated based on specified COKC process model. This process has six phases where the functionality of the tool differs from one phase to another phase. It supports two different roles (the participants and the problem owner), each with its different responsibilities.

There are some common requirements that span the different phases for the whole team. These are:

1. Team members and Problem Owner should be allowed to participate in every group discussion (except for Problem Owner who is being restricted to participate in Integration group discussion).
2. Team members should be allowed to load any previous notes from the group discussion map.
3. Team members should be allowed to view supporting documents and get access to specified URL on the Internet.
4. Team members should be allowed to make a virtual copy of notes selected to Personal Notebook.
5. Team members should be allowed to quote note from previous contribution to discussion.

Other requirements vary from one phase to another. They are presented along the COKC process model as follows:

Articulation Phase

<u>Participants</u>

1. View statement of issue

KC-Space should be able to display the *Statement of Issue Window* for participants to view. The window should display the *Statement of issue* with its attachment of supporting document (for example Word, PDF document) and specified URL attached to it (if any) Besides it has the navigational links in which the participants can select upon. Links include *Post Position* pertaining to the *Statement of issue* at hand and *Copy* options to make a virtual copy of the *Statement of issue* to *Personal*

Notebook. The supporting document and other resources from external link should be viewed in a separate window other than the main window.

2. Articulate Statement of issue

Upon selecting the *Post Position* option, the participants should thereafter be able to articulate the issue using the *Articulation Editor*. Once the participants completed submitting the position, he/she has to be able to notify the Problem Owner and other participants who have submitted their position earlier. When submitting is done, the participants can no longer post their position, as each participant is limited to place one position for a particular issue. Once the position is submitted, it has to be shown in the *Comparator*. At this point, the participants should not be allowed to view others contributions as this stage is done individually and independently.

<u>Problem Owner</u>

1. Change phase

The Problem Owner has nothing to do with this phase. This phase continues until the specified dateline. The participants who were late in posting were considered excluded from the group. However, if the group consists of less than four members, the Problem Owner should then be able to extend the dateline.

Comparison Phase

Participants

1. Participants view on others contribution of positions

KC-Space should be able to display the *Comparator* for participants to view other participants' positions and should be displayed in the main window.

Problem owner

1. Change phase

Problem owner should be able to view positions submitted by all participants. Moreover, problem owner should be able, at any time, to declare this phase over and move the process to the following phase. In such case, KC-Space has to generate an automatic notification for all participants.

Argumentation Phase

Participants

1. Argumentation discussion

KC-Space should be able to display explicit representation of *Argumentation Discussion Map* and thread, upon which the participants can retrieve and respond to existing notes. This should be done when the participants select the node from the argumentation discussion map. KC-Space then should display the contents of selected notes in the main window with its attachment of supporting document (for example Word, PDF document) and specified URL attached to it (if any). The supporting documents and external link of other web resources should then be viewed in separate window other than the main window. The participants should be notified by email whenever someone replies to his/her thread notes.

Problem owner

1. Change phase

At this point, the problem owner should be able to decide when to move the argumentation process to the next phase by looking at the map. When this happens, KC-Space should notify all participants that the negotiation phase has started.

Clarification Phase

Participants

1. Post new term

Participants should be able to post new 'term' for a group to communicate its meaning. Upon submitting, the KC-Space should be able to check if the 'term' submitted is already in existence. If so, KC-Space should then be able to prompt a proper message, otherwise the 'term' has to be shown in the *Clarification Discussion Map*.

2. Clarification discussion

Each node 'term' in the *Clarification Discussion Map* should be linked to its contents in the main window. Participants then should be able to view the contents and respond to the 'term' posted by one another, argue with or against another or perhaps negotiate the 'term' used in various competing claims and positions. The participants should be notified by email whenever someone replies to his/her thread. Clarification discussion for each 'term' should be carried out concurrently, therefore KC-Space should allow participants to scroll through the 'term' and view any discussion regarding them.

3. Summarise term

Using the selection list in the *Group Glossary Window*, participants then should be able to select the 'term' to sum up the discussion regarding them. When selecting, the participants should be able to compose summary of the discussion using simple form text editor. Once the 'term' has been summarised (henceforth called Group Glossary), it has to be automatically marked with locked 'term' and has to be shown in the map. At his point, the participant should still be allowed to change their *Group Glossary*. This should be done using email.

Problem owner

1. Change phase

Once all 'terms' has been summarised, he/she should then be able to move the clarification process to the next phase. When this happens, KC-Space should notify all participants that the negotiation phase has started.

Negotiation Phase

Participants

1. Contribute Knowledge Negotiation

The participants should be able to specify which note he/she wishes to revise by selecting the *Reflect Previous Thinking* options from the editor toolbar. KC-Space should do this by automatically loading the selected notes from argumentation map to the simple form text editor. The participants thereafter should be able to revise the notes he/she previously selected using the editor. The contribution (henceforth is called Knowledge Negotiation Note) should be classified into several categories, namely annotate, and summarise. Once the Knowledge Negotiation Note has been submitted, it has to be shown in the *Negotiation Discussion Map*.

2. Negotiation discussion

It follows the same requirements as of argumentation discussion.

3: Explicit rating

Participants should be able to rate the *Knowledge Negotiation Notes*, each of which should only be rated once. He/she either rates the note as High, Medium or Low. The note is considered accepted if more than half of the number of participants accepts it. Otherwise, it is considered rejected.

Problem owner

1. Change phase

Problem owner should be able to declare this phase over and move the process to the phase that follows. In such a case, KC-Space has to generate an automatic notification for all participants.

Integration Phase

Participants

1. Contribute element of article

KC-Space should be able to load a frameset that is comprised of two frames (top and bottom) in the same window display. The top frame shows the currently composed *Group Reflective Article.* The bottom frame displays the *Integration Discussion Map,* which provides mapping discourse of students who work collaboratively to construct the article. Upon selecting the *Contribute Element of Article* option, the participants should thereafter be able to write their contribution of element for their group article using the text editor or be able to provide additional documents by downloading graphic, sound, or video to the list of elements.

2. Integration discussion

It follows the same requirements as of argumentation discussion.

Problem owner

1. Compose article

KC-Space should be able to load a frameset that is comprised of two frames (top and bottom) in the same window display. The top frame shows the *Document Explorer* in which articles are displayed as icons in a familiar Explorer-like window and can be extracted by simply clicking the icons. The bottom frame displays the *HTML Text Editor*, which facilitate the problem owner to compose and edit the so-called *Group Reflective Article*. Upon composing the article, the problem owner should be able to retrieve the participants' contribution of elements and copy them to the *HTML Text Editor*.

KC-Space Non-functional requirements

KC-Space tools are intended as prototypes to show a proof of concept of how such collaborative tools can be built, and are not necessary robust or bug-free.

4.1.2 KC-Space Object-oriented Analysis (OOA)

Identifying KC-Space use-cases

KC-Space implements collaborative knowledge construction process where the functionality of KC-Space differs from one phase to another. The different use-cases are identified according to the different phases. Each use-case is usually described by using a scenario. There are twenty-two use-cases identified through the process. The use-cases are described below. However, their respective scenarios and diagrams are found in Appendix A. Only three of them are shown in this chapter.

Articulation phase

There are eight use-cases in this phase. Figure 4.1 shows these eight use-cases of Articulation phase.

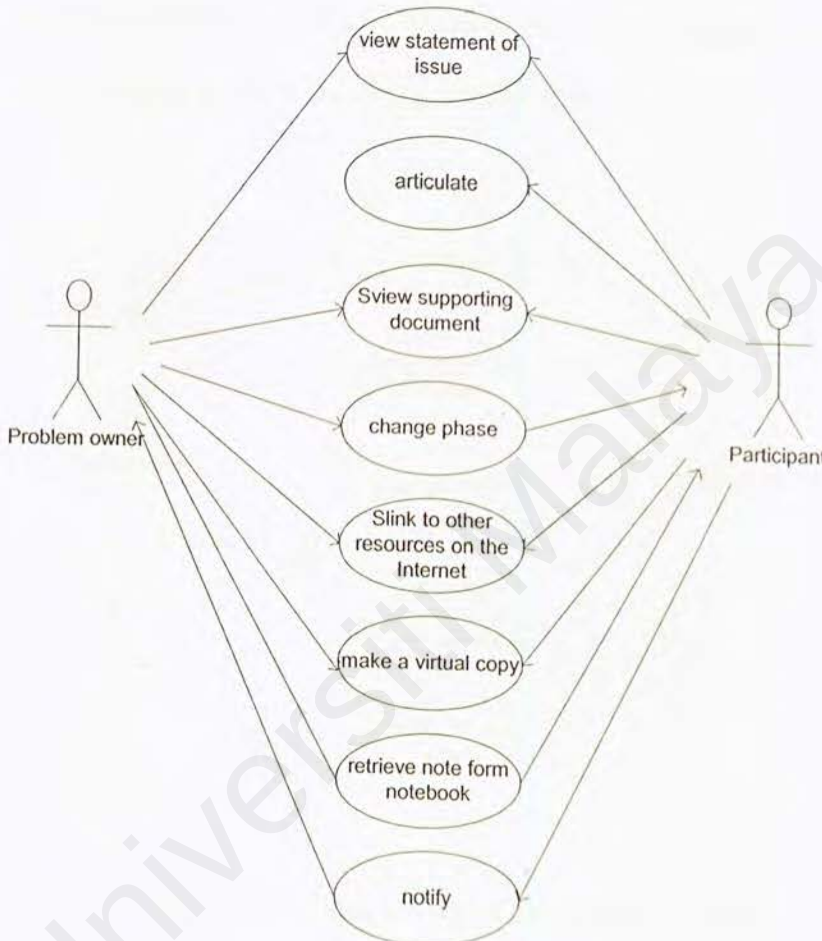

Figure 4.1: Articulation phase use-cases

Comparison phase

In this phase, there are five use-cases identified (see Figure 4.2). Both the problem owner and participants are allowed to view their team members' positions, view supporting document, link to other resources on the Internet and make a virtual copy of notes selected to Personal Notebook. However, only the problem owner is allowed to move the comparison phase to the argumentation phase.

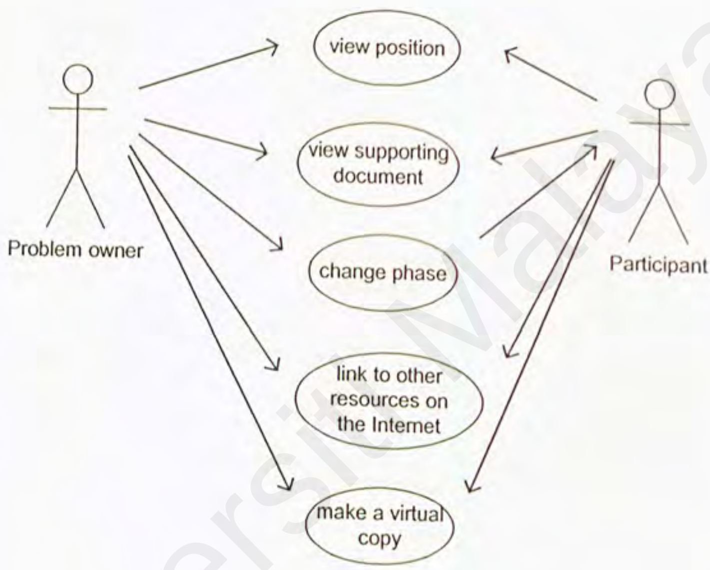

Figure 4.2: Comparison phase use-cases

In addition to the previously identified use-cases, there are two other use-cases identified in this phase. In the first use-case, both the participants and problem owner is allowed to participate in the argumentation discussion. In the second use-case, KC-Space interacts with the participants and problem owner by notifying them through electronic mail when important events have taken place (replies to the thread note). Figure 4.3 shows the use-cases of Argumentation phase.

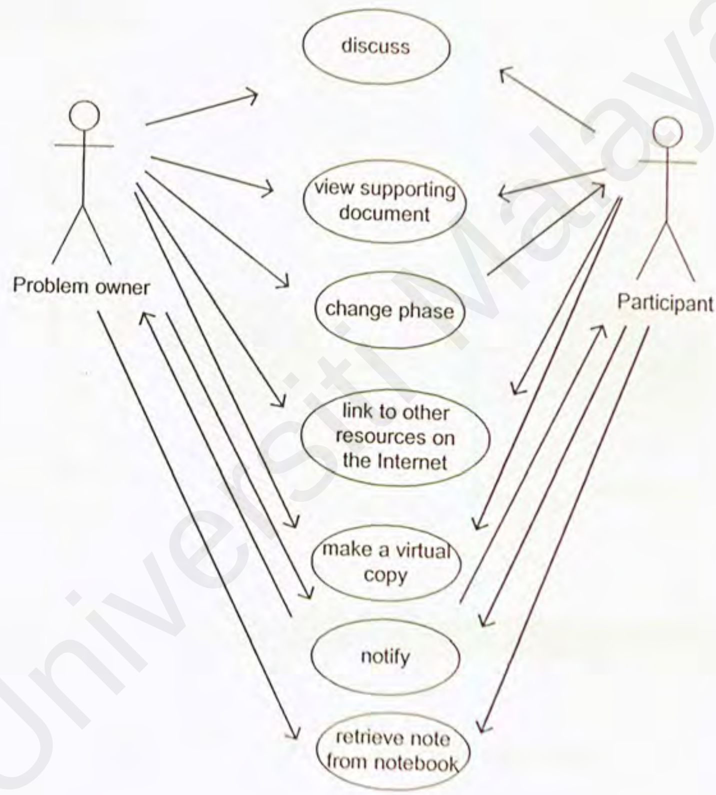

Figure 4.3: Argumentation phase use-cases

4.2 KC-Space design

In order to fulfil the requirements identified in the analysis part, the following considerations were taken into account.

4.2.1 KC-Space architecture

KC-Space has been design based on the client/server architecture. The system employs the Internet Information Server (IIS) as the web server, and Cold Fusion Mark Up Language (CFML) as a server-side scripting environment to create and run dynamic, interactive Cold Fusion applications. The overall architecture of the system is illustrated in Figure 4.4.

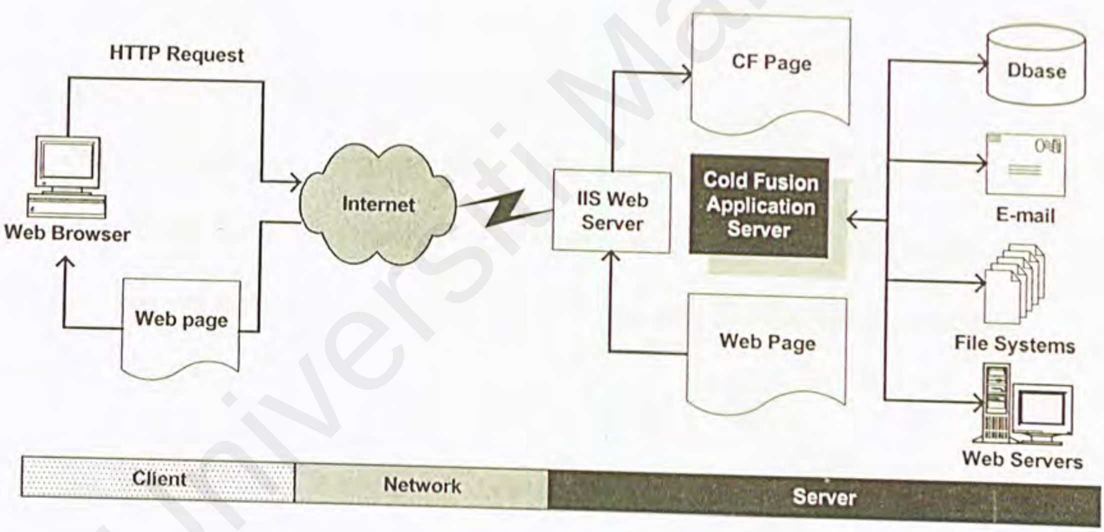

Figure 4.4: The KC-Space architecture

When a browser requests a page in a Cold Fusion application, Cold Fusion Application Server processes the CFML and dynamically generates a Web page that is returned to the browser.

1. When a user clicks a "Submit" button on a form or a hypertext link on a KC-Space page, the user's Web browser sends an HTTP request to the IIS Web server via the Internet.
2. The Web server passes the data submitted by the client and the appropriate page to the Cold Fusion application server through a server API.
3. Cold Fusion reads the data from the client and processes the CFML in the page. Based on the CFML, Application Server interacts with database servers, the file system, SMTP servers.
4. Cold Fusion dynamically generates a Web page that is returned to the Web server.
5. The Web server returns the HTML page to the user's browser.

4.2.2 KC-Space Object-Oriented Design (OOD)

There are twenty-two use-cases identified in the analysis phase. For each use-case, there should be an interaction diagram. The complete scenarios and their respective interaction diagram are presented in Appendix A. Only four of them are shown in this chapter.

Participant articulates issue scenario

1. The participant selects to post 'position' regarding the issue at hand
2. The problem Statement Window checks if participant can post the 'position'
3. The client displays the editor
4. The participant articulates the issue using the Articulation Editor
5. The participant posts his/her position and passes to the client
6. The text editor calls the client to pass the 'position'
7. The server updates the database
8. The server notifies other participants via email

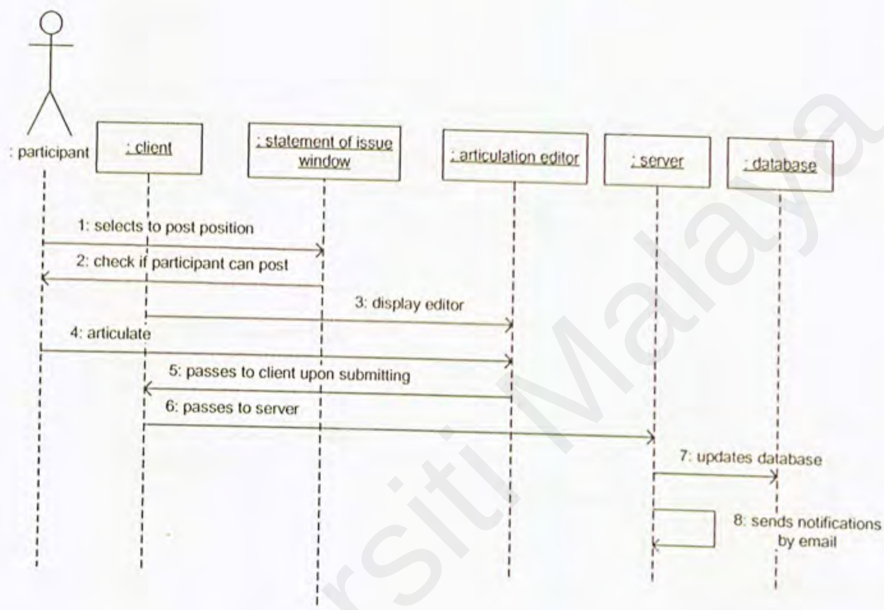

Figure 4.5: Participant articulates issue diagram

Participant participates in group discussion scenario

1. The participant selects the note to retrieve from the Group Discussion Map
2. The client displays the note in the main window
3. The participant selects to reply to the note retrieved
4. The main window checks if participant can reply
5. The client displays the editor
6. The participant replies to the note retrieved
7. Passes to the client upon submitting
8. The client passes to the server
9. The server updates the database
10. The server notifies other participants via email.

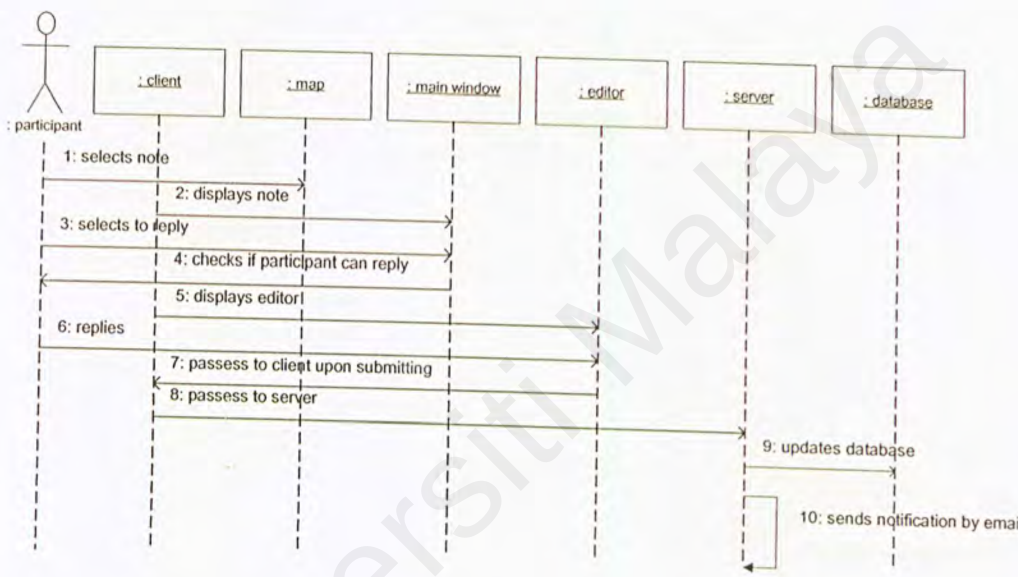

Figure 4.6: Participant participates in group discussion diagram

Participant participates in Clarification discussion scenario

1. The participant selects the note to retrieve from the Clarification Discussion Map
2. The client displays the notes in the main window
3. The participant selects to reply
4. The main window checks if the term is locked
5. The client displays the editor
6. The participant replies
7. Passes to the client upon submitting
8. The client passes to the server
9. The server updates the database
10. The server notifies other participants via email

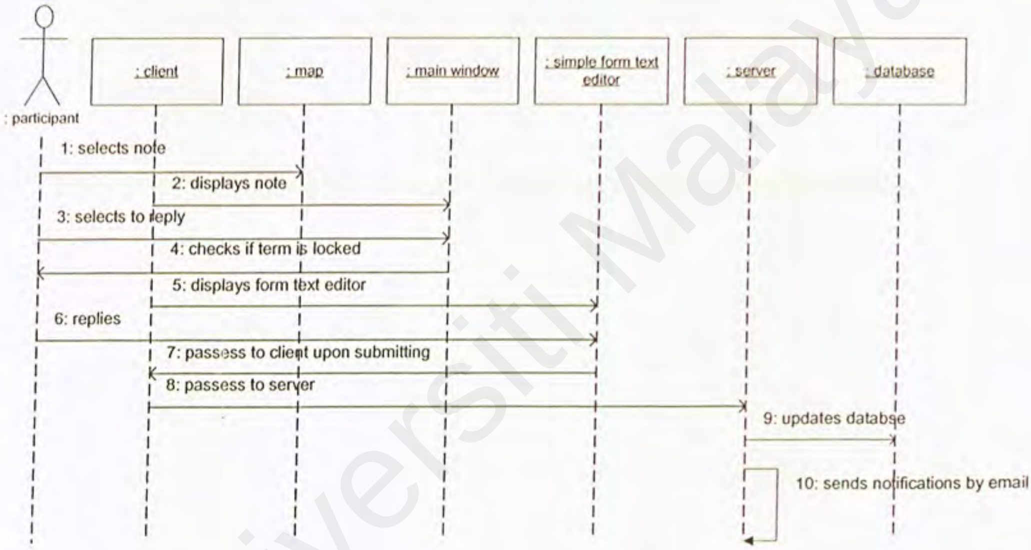

Figure 4.7 Participant participates in Clarification discussion diagram

Participant views others contribution of positions scenario

1. The participant selects to view the 'positions'
2. The client displays the Comparator
3. The participant selects the 'position'
4. The client shows the main window with the selected 'position'

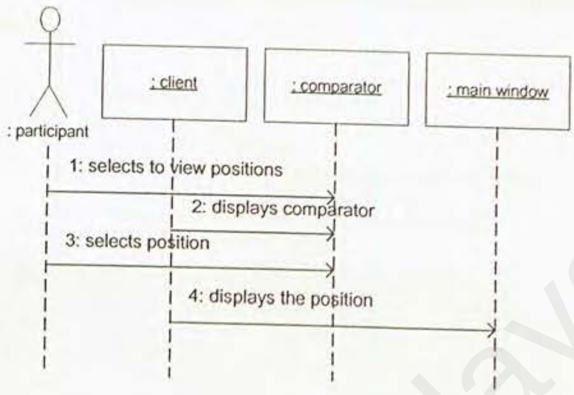

Figure 4.8: Participant views others contribution of positions diagram

4.2.3 KC-Space User Interface Design

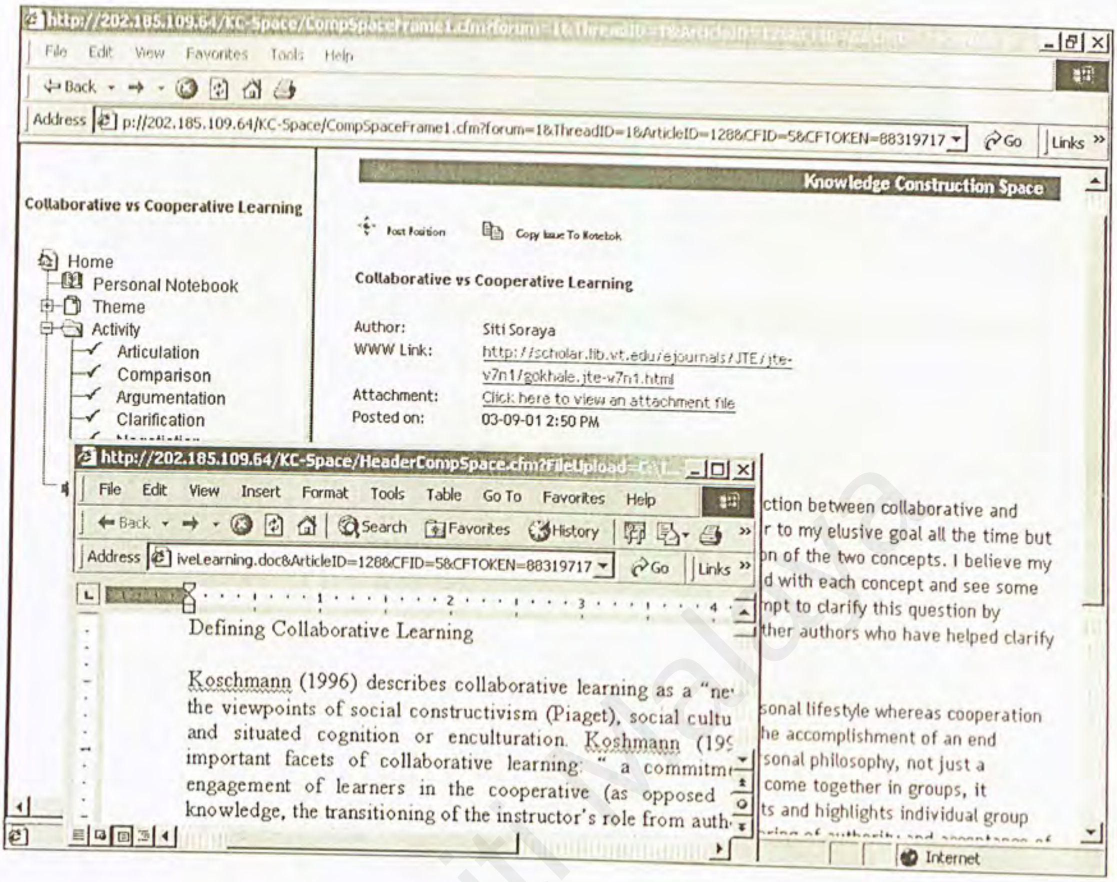

Figure 4.9: Typical user view of KC-Space during Articulation phase

Figure 4.9 represents a typical user view of KC-Space during the Articulation phase. The screen consists of two windows: one occupies the entire left half of the screen, and the other one occupies the remaining portion of the screen. The left window is for displaying the navigational tools (in the form of the Explorer-like Windows), which facilitates the users to navigate around the KC-Space. The remaining window is used to displays the *Statement of Issue* with its attachment of supporting document (for example Word, PDF document) and specified URL attached to it (if any). The supporting document and other resources from external link is viewed in separate window other than the main window. All the-user level commands are available as icons where user may simply click on the icons through mouse clicking.

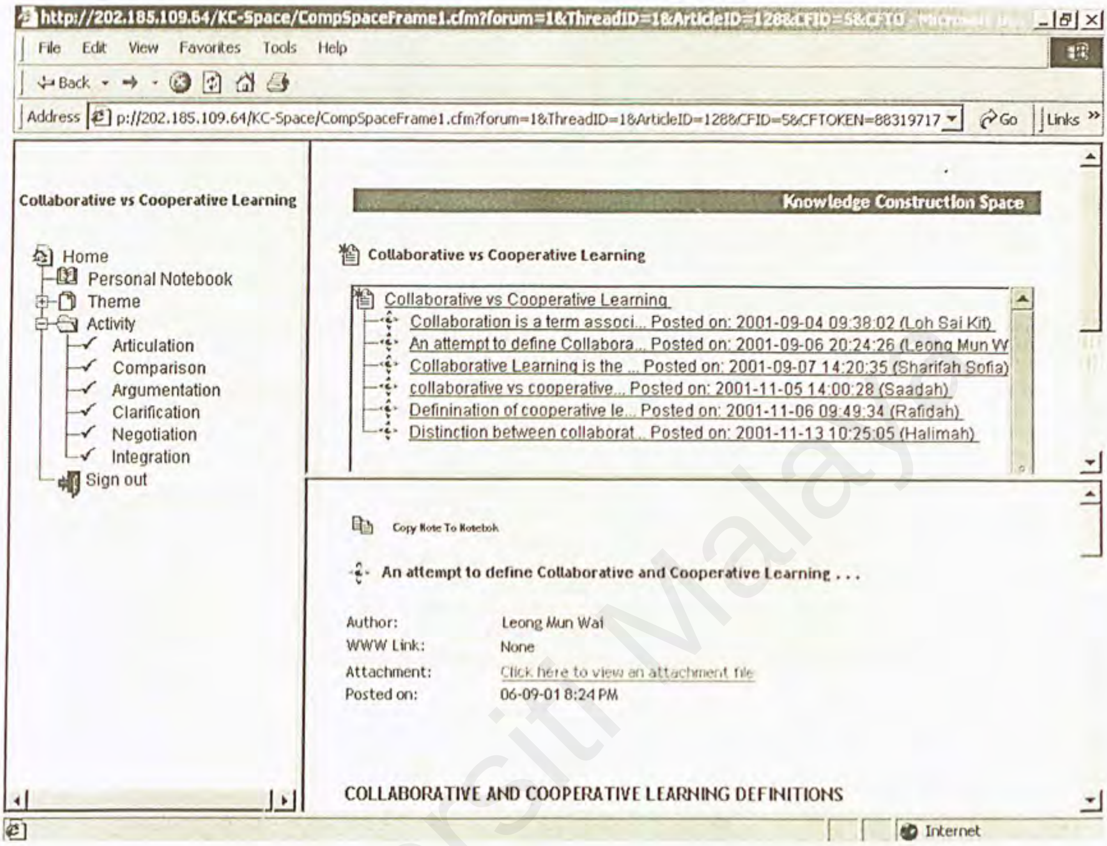

Figure 4.10: Typical user view of KC-Space during Comparison phase

Figure 4.10 is a typical view of KC-Space during the Comparison phase. The screen consists of three windows: one occupies the entire left half of the screen, and the other two equally divided up the remaining portion of the screen. The left window is for displaying the navigational tools (in the form of the Explorer-like Windows). The upper windows contains a comparative view of the students' perspectives generated from the previous phase. In the example shown, it is a listing of students' perspectives by 6 participants of the current session. The highlighted text (with the underline font) represents the links to the corresponding note with its attachment of supporting document and specified URL attached to it in the lower window. The supporting documents and external link of other web resources is viewed in separate window other than the main window.

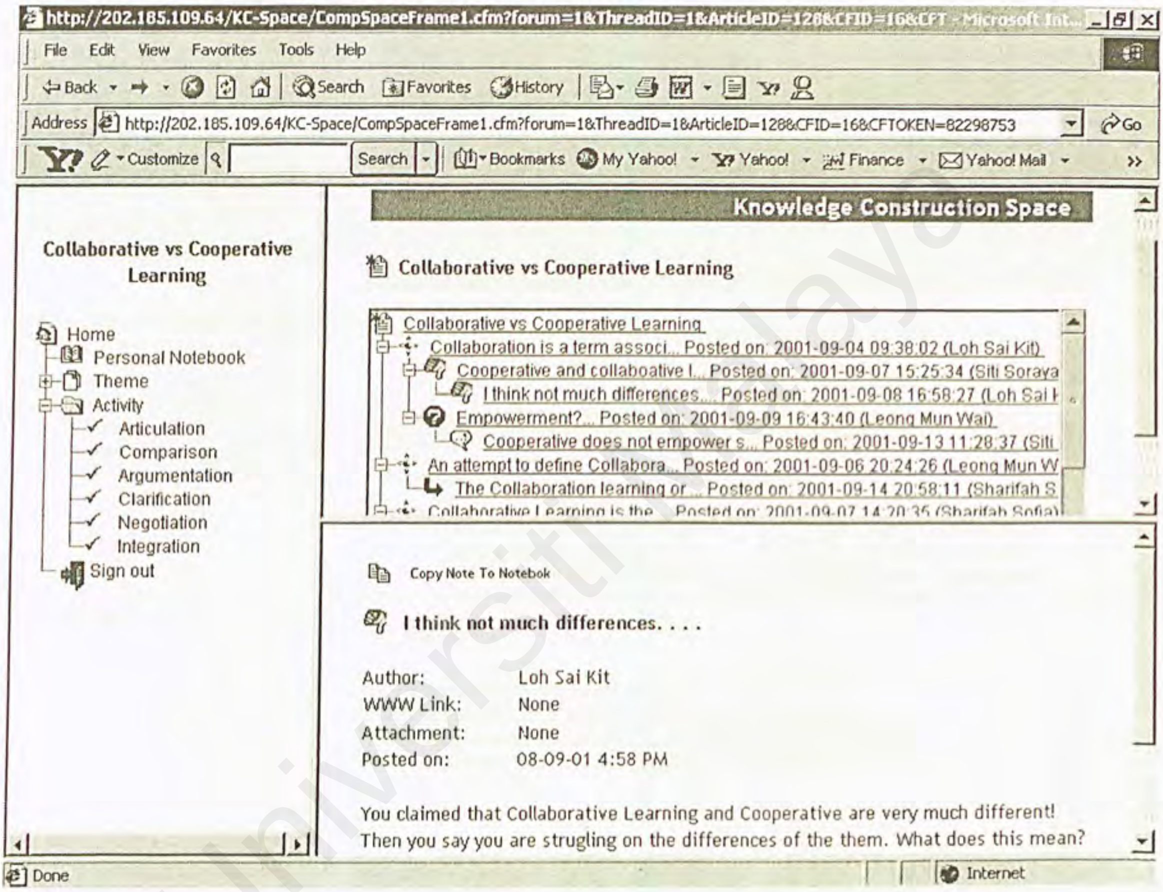

Figure 4.11: Typical user view of KC-Space during the group discussion phase of collaborative knowledge construction process

Figure 4.11 is a typical view of KC-Space during the group discussion phase of collaborative knowledge construction process. The upper left window contains a explicit representation of conversations and discussions, and thread. In the example shown, it is an argumentation map structure that uses the concepts of issues, positions, arguments, elaborations, questions and answers to organize the discourse in a manner, which is richer and more precise than simple "thread" mechanism typical of discussion forum. The argumentation structure provides a link to the corresponding note that contains more detailed information, for example the attachment of supporting document and specified URL attached to it.

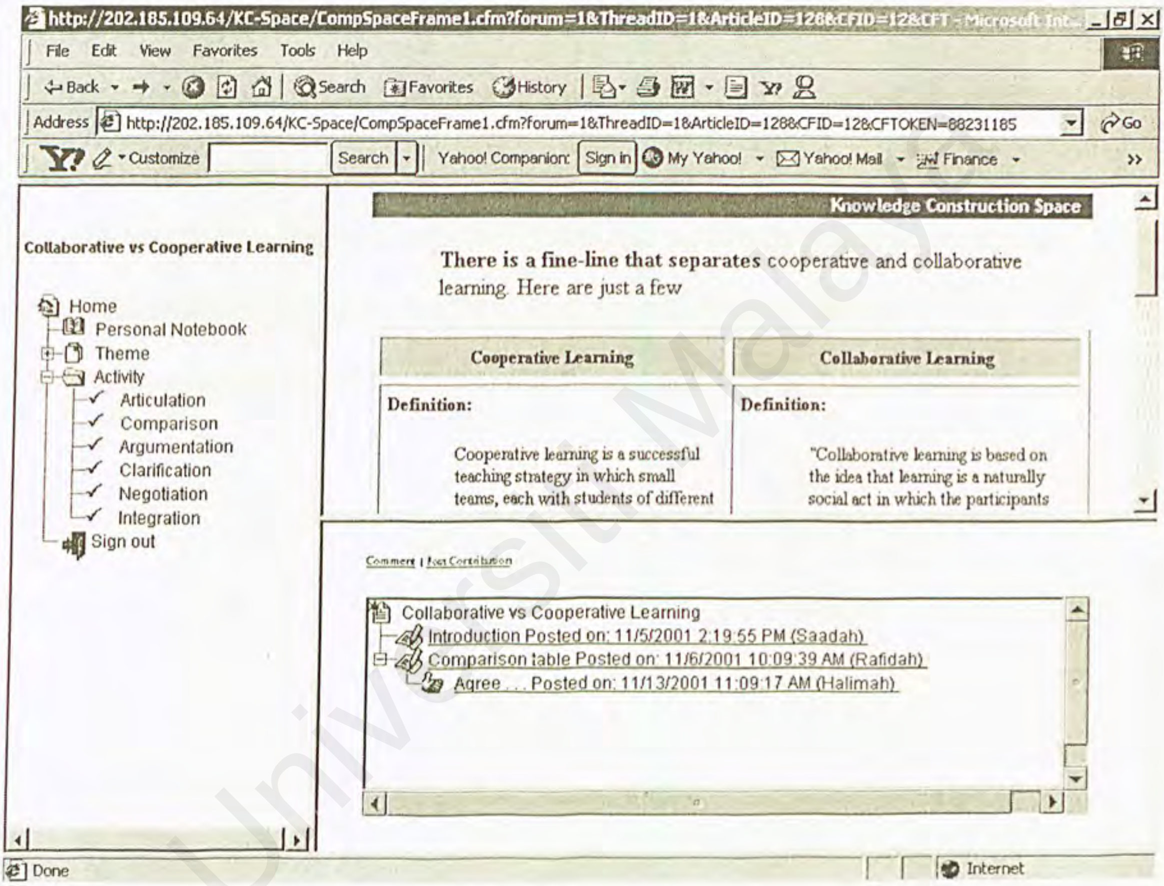

Figure 4.12: Typical user view of KC-Space during Integration phase

Figure 4.12 represents a typical user view of KC-Space during the Integration phase. The screen consists of three windows: The navigational tools (in the form of the Explorer-like Windows) occupy the entire left half of the screen, and the other two equally divide up the remaining portion of the screen. The upper-right window is for displaying the current Group Reflective Article. The lower-right window is used to displays the Integration Discussion Map that provide mapping discourse of students who work collaboratively to construct the Group Reflective Article.

4.3 Summary

This chapter presents KC-Space analysis and the design. In the first part of this chapter, KC-Space functional and non-functional requirements have been stated. This has been followed by object-oriented analysis where the different use-cases with their respective scenarios were identified. In the second part, KC-Space architecture has been presented. This has been followed by the object-oriented design where the use-cases identified in the analysis part have been transformed into interaction diagrams. Finally, some aspects of KC-Space user interface design have been presented.

Chapter 5

KC-Space Implementation and Execution

This chapter presents the different aspects of KC-Space implementation and its execution. The first section begins by describing the implementation environment where the communication infrastructure, the implementation programming language, the database option and the web server are described. In the second part of this section, KC-Space main objects and their implementation are presented. In the following sub-section, the implementation of KC-Space's main features is shown. The second section of this chapter shows the running of the different phases of knowledge construction process using KC-Space.

5.1 KC-Space implementation

Many elements were used to implement KC-Space. Some of these elements are related to the development environment and some others are related to the technical aspects of KC-Space's functions. These elements are described below.

5.1.1 The communication infrastructure

The most important motivation building KC-Space was the exploration of the WWW as a medium of communication in building collaborative tools. The WWW offers a number of characteristics over the other available communications mediums. These are as follows:

- The WWW is a platform-independent. This allows the same code to be run on different operating system such as Windows and Unix.

- The WWW is global
- No accessing time limits. This allows users to access any of the following at anytime and from any location.

5.1.2 ColdFusion Markup Language (CFML)

ColdFusion has been chosen to implement KC-Space. ColdFusion consists of several components that can create the powerful development and deployment environment for web applications. These components are: (1) ColdFusion Markup Language or CFML, (2) ColdFusion Application Server. CFML is a close relative to the Hypertext Markup Language (HTML), it is tag based. However, CFML is very much difference with HTML: CFML is used to specify actions to take in the form of small server-based programs while HTML is used to define the structure, and to some extent, the layout and design of a web page. The ColdFusion Application Server offers numerous features that make development and deploying reliable, robust, and high-performance KC-Space possible. These include:

Open approach with other technologies for integrity

ColdFusion uses its own customized scripting tags, which when embedded in a Web page and consequently read by the Web server, produce on-the-fly dynamic output for the end user. The scripting elements are invisible to the client. To the browser, it appears as if they are normally surfing any Web site. CFML (ColdFusion Markup Language) is browser independent, although when combined with other technologies such as DHTML and XML, the end product will require a high-end, more modern browser.

Scalability and high performance

ColdFusion is proven tool for developing high performance, scalable web application. It support Microsoft technologies including Windows NT / windows 2000, COM/COM+, Internet Explorer, IIS, and BackOffice.

Platform Independence for flexibility

ColdFusion provides platform independence by additionally running on Linux, Solaris, and HP-UX. Besides, the combination of multiple operating systems and HTTP server support for all of the major web servers gives ColdFusion applications maximum flexibility of future choice.

5.1.3 ColdFusion Application Server Enterprise

KC-Space deploy on the ColdFusion Application Server Enterprise. The server is actually a service that hooks into the web server, extending its capabilities to allow it to "understand" CFML. The server supports server clustering and dynamic fail-over, which means if one of the web servers goes down, the others will pick up where it left off, leaving the end users with uninterrupted service. Being multi-threaded, the ColdFusion server can pool threads to speed connectivity.

5.1.4 Internet Information Server as web server

As for the web server support, clustering and fail-over require that the sites be running Internet Information Server on Windows platform. Thus, KC-Space relies heavily upon Microsoft's Internet Information Server as a web server.

5.1.5 The database

There are many database management system (DBMS) tools on the market running on various hardware platforms. The top DBMS products have one feature in common: All support SQL data access and manipulation. SQL is an acronym for Structured Query Language. This industry-standard language is designed to create, manipulate, and control data in relational database. ColdFusion Application Servers Enterprise includes native drivers that support access to databases for any version of Windows operating systems. It provides connection with the database system via SQL, since ColdFusion is an Open Database Connectivity (ODBC) client. For such reason, Microsoft access database has been chosen to collect and manipulate data. This choice was made for its simplicity and powerful capabilities.

5.1.6 KC-Space objects

KC-Space is composed of several objects used to accomplish the collaborative knowledge construction process. The most important objects are:

Statement of issue Window. This object is used to allow users to view *Statement of Issue* at hand. The window displays the *Statement of Issue* with its attachment of supporting document (for example Word, PDF document) and specified URL attached to it (if any). The supporting document and other resources from external link are viewed in separate window other than the main window.

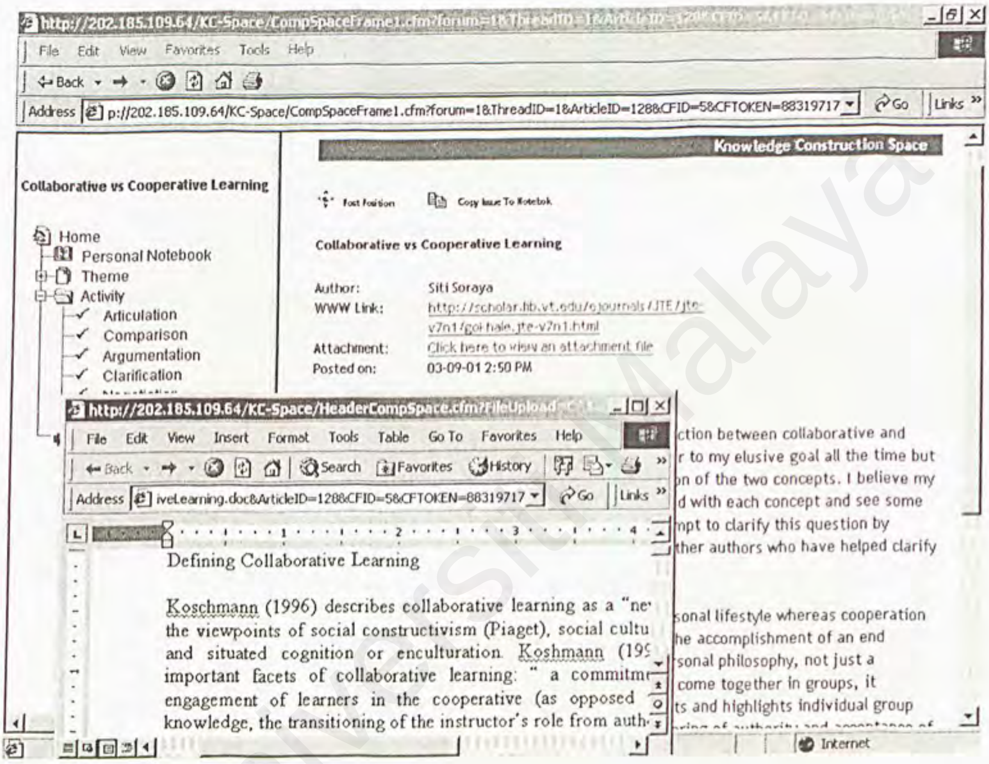

Figure 5.1: Statement of Issue Window

Articulation Editor. It facilitates the process of articulating ideas pertaining to a given issue. The *Articulation Editor* provides facilities for users to articulate the issue in HTML format. The HTML option enables users to include links to Internet sites, display images or format their messages (fonts, colours) using conventional html tags. It also allows the users to load composed notes from their respective *Notebook* and to quote previous message within their notes. Besides, users can include specified URL to link to other resources on the WWW or provide attachment of supporting document. Once the user has completed submitting the position, he/she can be notified by email whenever someone replies to his/her thread notes.

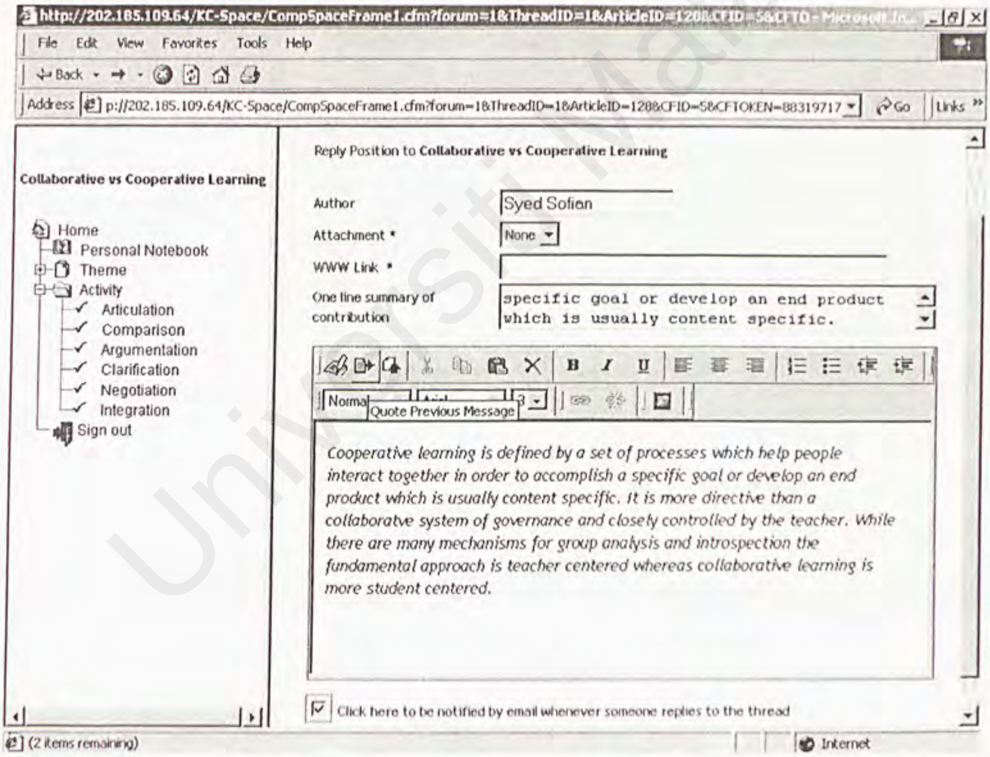

Figure 5.2: Articulation Editor

Comparator. It contains threaded notes of users' perspectives from a shared repository that are tagged as being visible within a particular issue. The *Comparator* has been designed to offer some facilities for users to view others' contribution of perspectives with its attachment of supporting document (for example Word, PDF document) and specified URL attached to it (if any). The supporting document and other resources from external link are viewed in a separate window other than the main window.

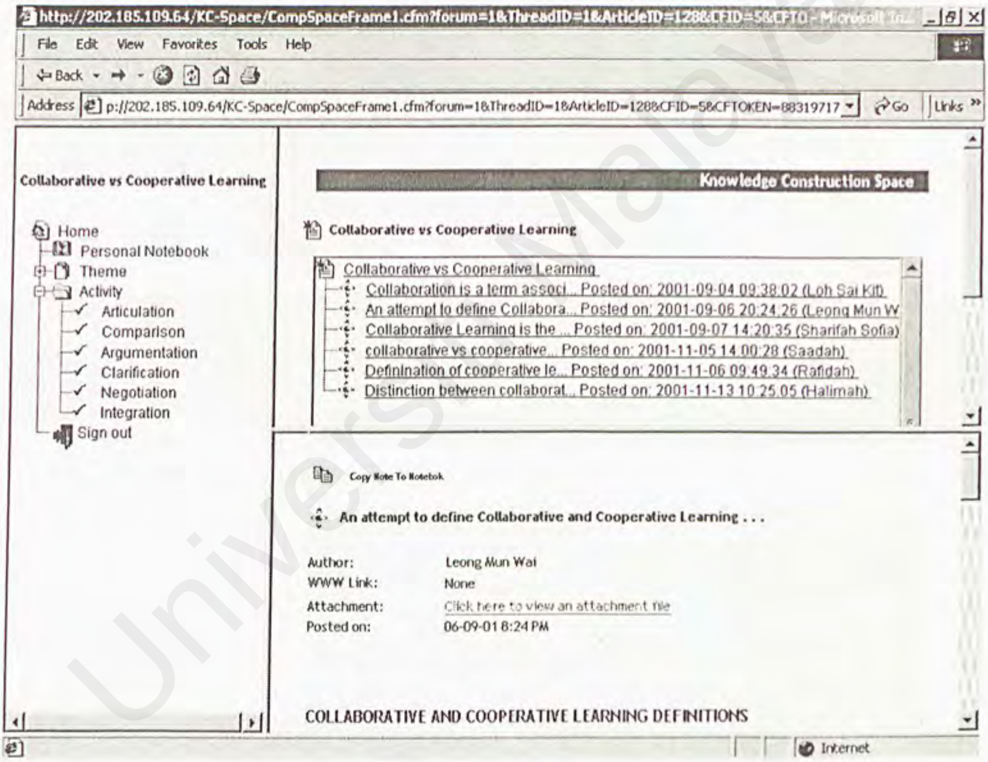

Figure 5.3: Comparator

Argumentation Discussion Map. The map allows explicit representation of conversations and discussions, and threads notes. The map uses the concepts of issue, position, argument, elaborate, question and answer to organize the discourse in a manner, which is richer and more precise than simple "thread" mechanism typical of discussion forum. The argumentation structure provides a view on the note when the users select the node from the *Argumentation Discussion Map*. The note is viewed in the main window with its attachment of supporting document and specified URL attached to it. The supporting documents and external link of other web resources are viewed in a separate window other than the main window. The users can record their opinion and participate in a discussion summarized in an argument map.

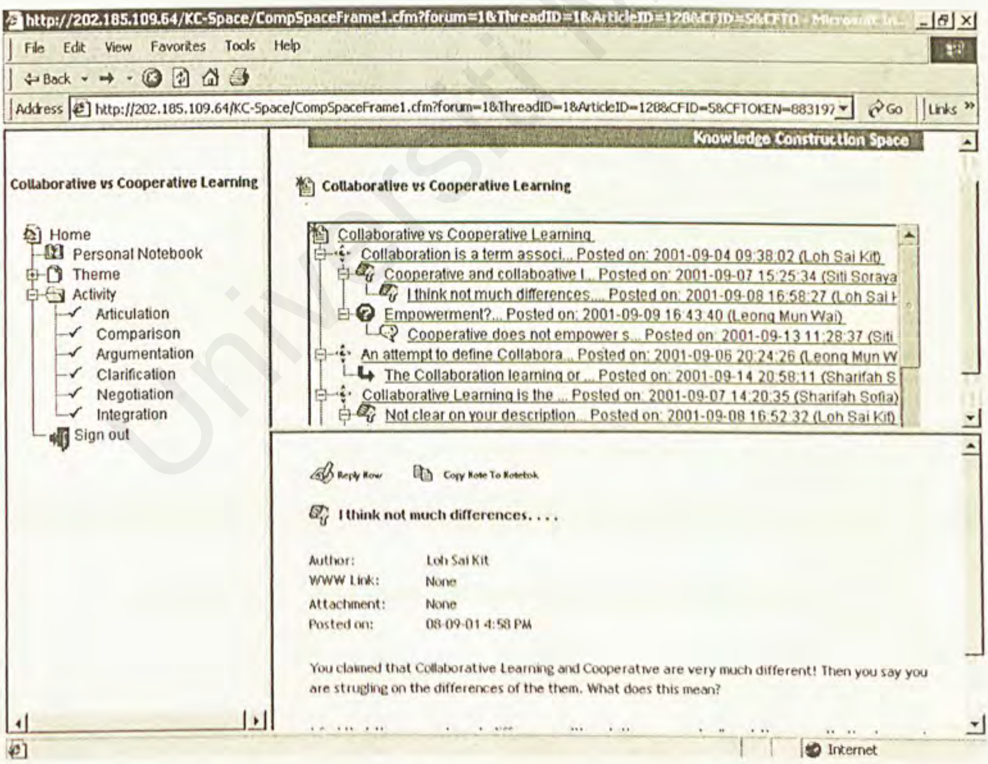

Figure 5.4 Argumentation Discussion Map

Argumentation Discussion Reply Editor. The editor is implemented to facilitate the users to reply to an existing note either by arguments to-support or arguments to-object position; to-ask or to-answer question; or to provide elaboration. It also allows the users to load composed notes from their respective *Notebook* and to quote previous message within their notes. Besides, users can optionally include specified URL to link to other resources on the WWW or provide attachment of supporting document. Once the user has completed submitting the position, he/she can be notified by email whenever someone replies to his/her thread notes.

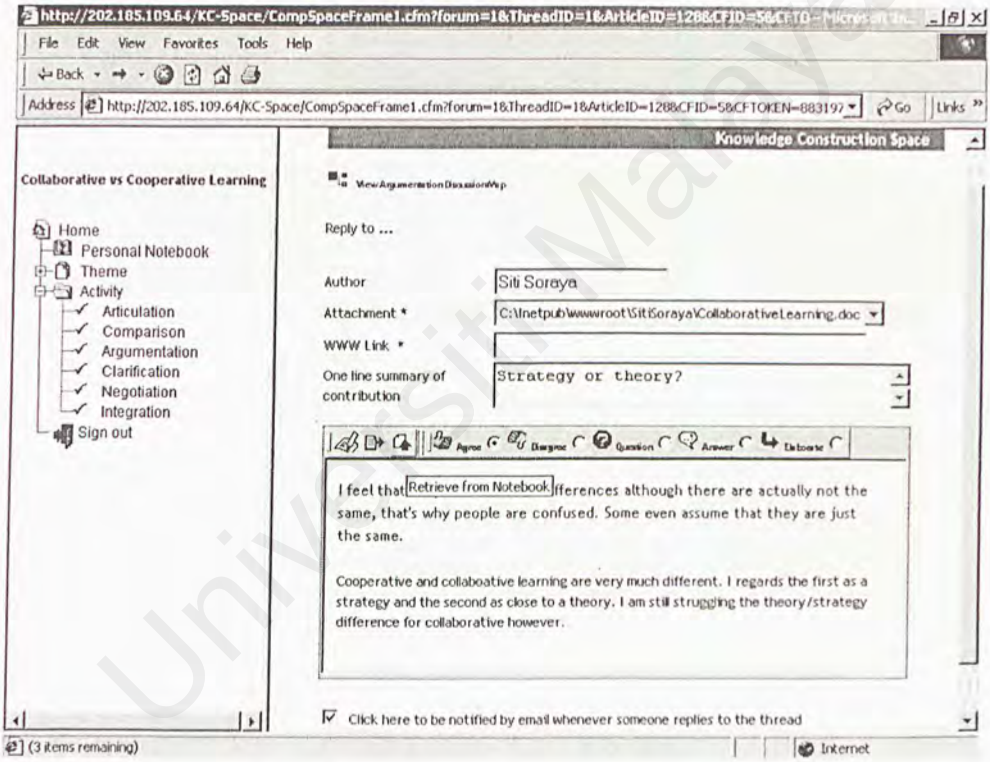

Figure 5.5: Argumentation Discussion Reply Editor

Clarification Discussion Map. The map structure is implemented by means of diagrammatic representation of discourse to facilitate the process of constructing group glossary. The map uses the concepts of term, claimed definition of term, argument, quote, question, answer and locked term to organize the discourse structure. Each node in the map is linked to its contents in the main window. The users can view the contents when selecting the node from the map and responding to the term posted by one another, argue for or against another, provide citation to an existing term or perhaps negotiate the term used by clarifying the differences in interpretation and terminologies in various competing claims and positions.

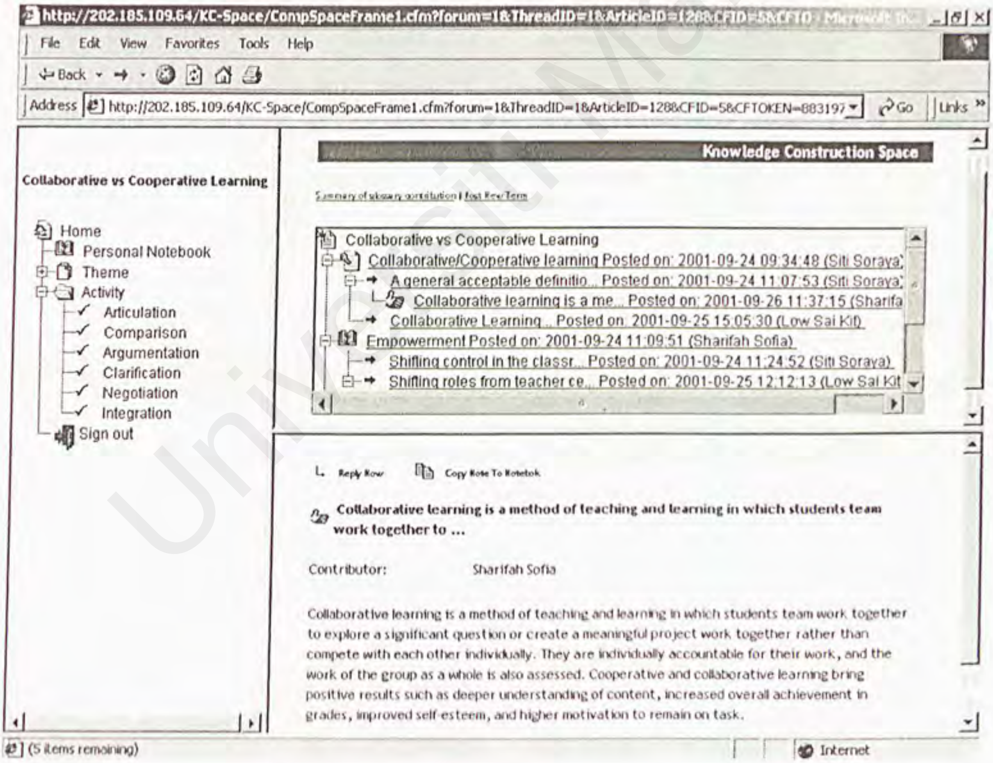

Figure 5.6: Clarification Discussion Map

Clarification Discussion Reply Editor. The editor is implemented to facilitate the users to reply to an existing note either by arguments to-support or arguments to-object position; to-ask or to-answer question. It also allows the users to quote previous message within their notes. Once the user has completed submitting the position, he/she has can be notified by email whenever someone replies to his/her thread notes.

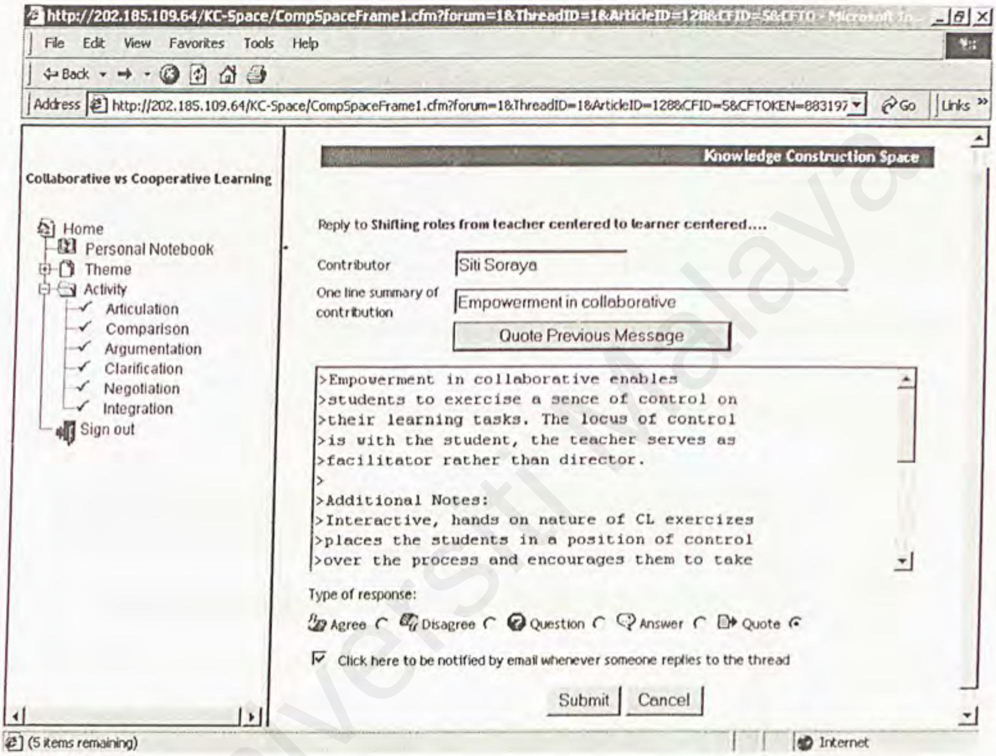

Figure 5.7: Clarification Discussion Reply Editor

Group Glossary Window. The selection list in the *Group Glossary Window* allows the users to select the term to summarise the discussion regarding them. Upon selecting, the simple form text editor is loaded to allow users to summarise the discussion (see Figure 5.8). Once the term has been summarised called as Group Glossary, KC-Space will automatically mark the term with locked term , which is then shown in the *Clarification Discussion Map*. The *Group Glossary* provides facilities such as searchable group glossary of the group knowledge contents.

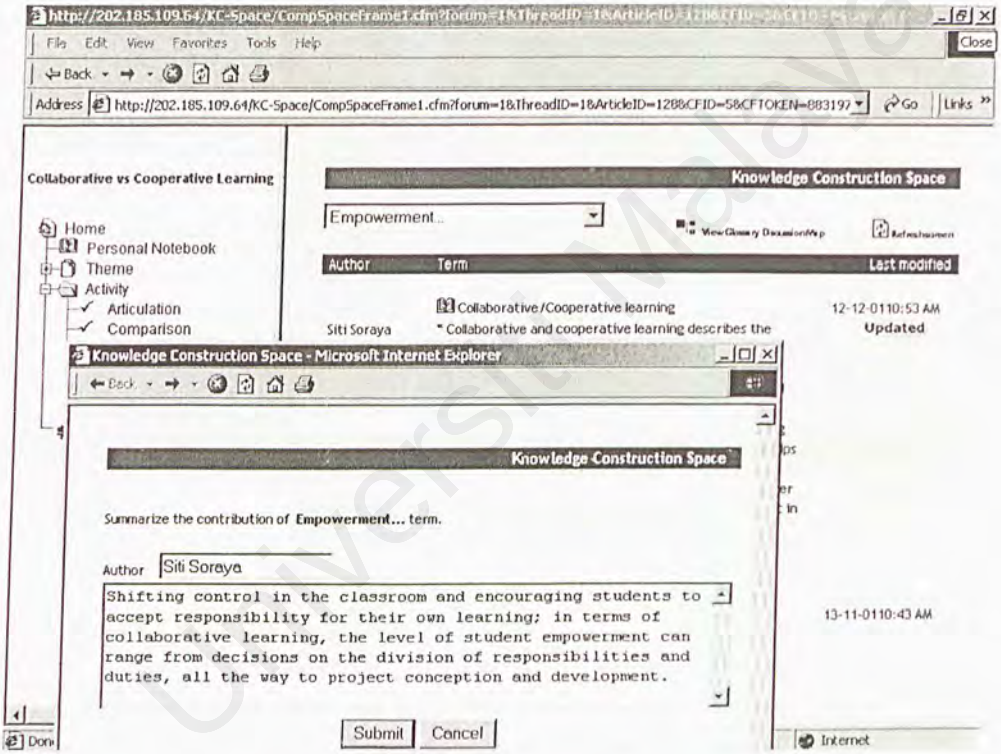

Figure 5.8: Group Glossary Window

Comment editor. This editor is used to submit comments on composed *Group Glossary* to authorized author by email. It also allows the users to quote previous glossary within their comments.

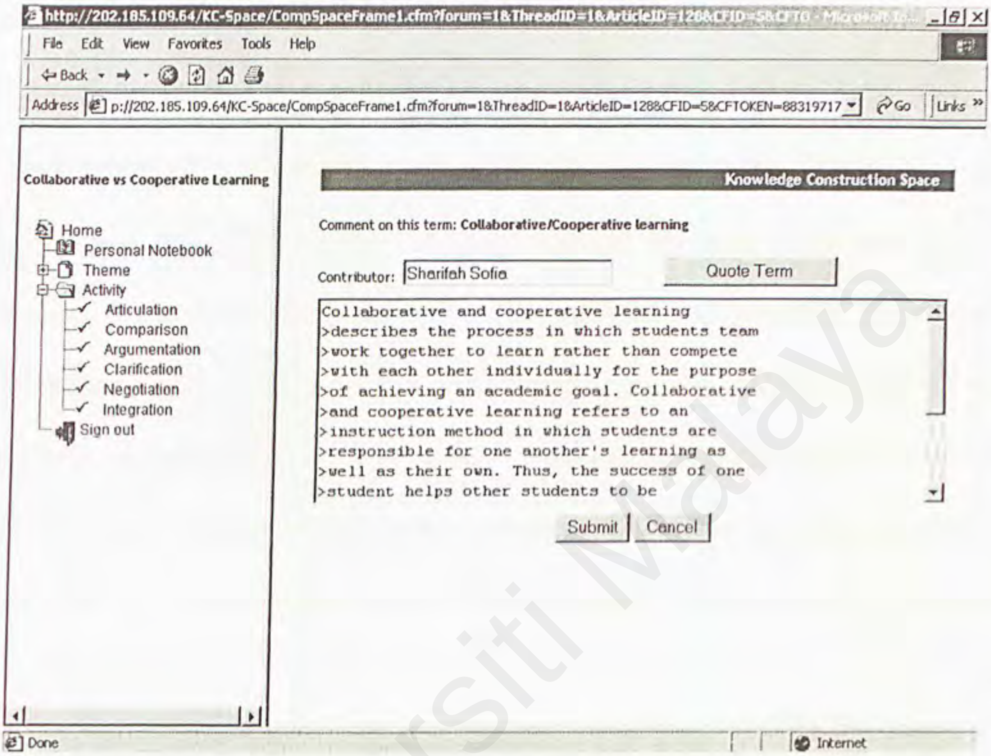

Figure 5.9: Comment editor

Knowledge Negotiation Notes Editor. This editor is implemented to facilitate users to collect, to organize, to relate ideas and to eventually add this contribution to the *Negotiation Discussion Map*. The editor offers the users to specify the note he/she wishes to revise by selecting *Reflect Previous Thinking* options from the editor toolbar. Upon selecting, the *Argumentation Discussion Map* is loaded in a separate window. The KC-Space will then automatically load users selected notes from the *Argumentation Discussion Map* to the editor for users to revise. The editor toolbar also provides the *Retrieve from Notebook* options where users can load the composed notes from their respective Notebook so as to contribute the so-called *Knowledge Negotiation Note*. The contribution can be classified into several categories, namely suggesting new ideas, to annotate, to rephrase, and to summarise note. Once the contribution has been submitted, this is shown in the *Negotiation Discussion Map* and the users can be notified by email whenever someone replies to his/her thread notes.

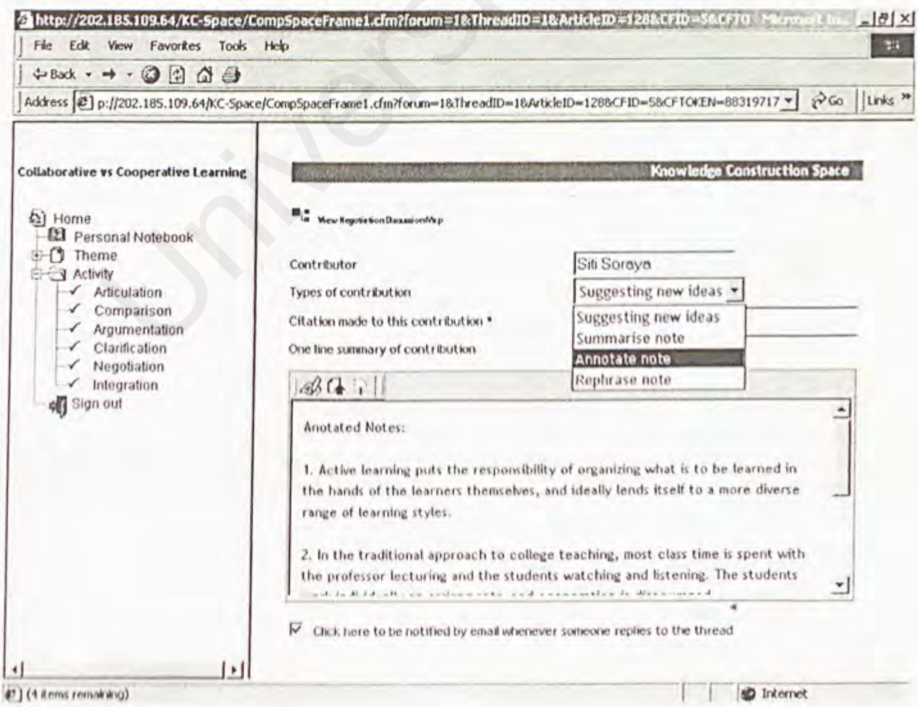

Figure 5.10: Knowledge Negotiation Notes Editor

Negotiation discussion map is used to facilitate the process of knowledge negotiation. The map uses the concepts of knowledge negotiation note, argument, question, answer, and elaborate to organize the discourse structure. Each node in the map is linked to its note in the main window. The users can respond to an existing note either by arguments to-support or arguments to-object position, to-ask or to-answer question, or to provide elaboration to the note concerned and rate the strength, relevance and usefulness of the *Knowledge Negotiation Note* along specific measurement that is high, medium, or low.

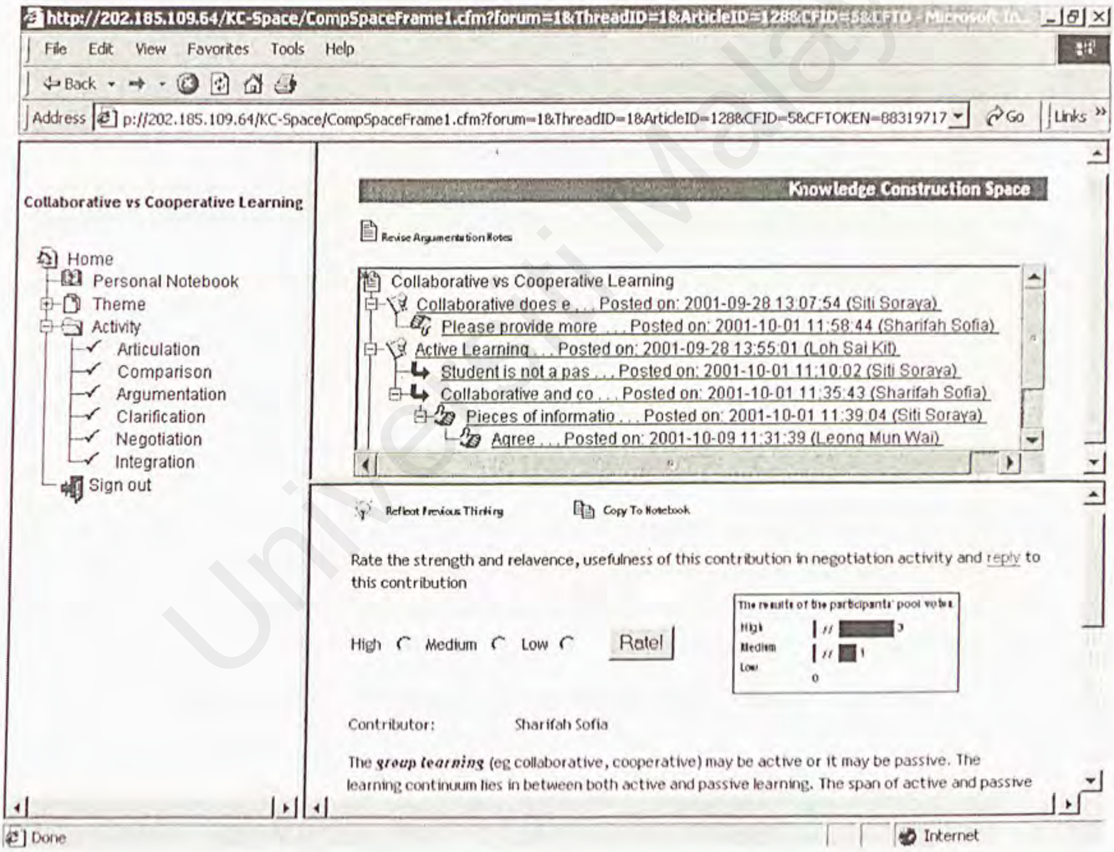

Figure 5.11: The negotiation discussion map

Negotiation Discussion Reply Editor. The object is implemented to facilitate the users to reply to an existing note in the negotiation phase either by arguments to-

Negotiation Discussion Reply Editor. The object is implemented to facilitate the users to reply to an existing note in the negotiation phase either by arguments to-support or arguments to-object position; to-ask or to-answer question; or to provide elaboration. It also allows the users to load composed notes from their respective *Notebook* and to quote previous message within their notes. Once the user completed submitting the position, he/she has can be notified by email whenever someone replies to his/her thread notes.

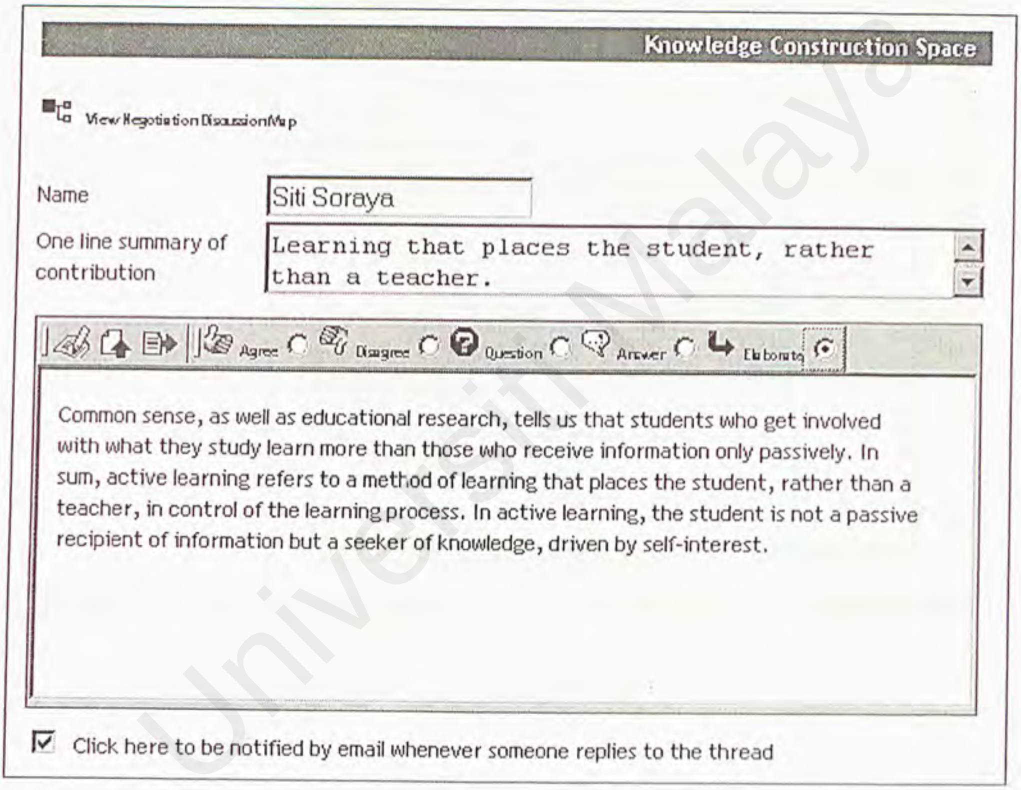

Figure 5.12: Negotiation Discussion Reply Editor

Integration Discussion Map provides mapping discourse of students who work collaboratively to construct the Group Reflective Article. The map uses the concepts of co-author's contribution of element of the article, argument, question, answer, and elaborate to organize the discourse structure. The upper-right window displays the current Group Reflective Article.

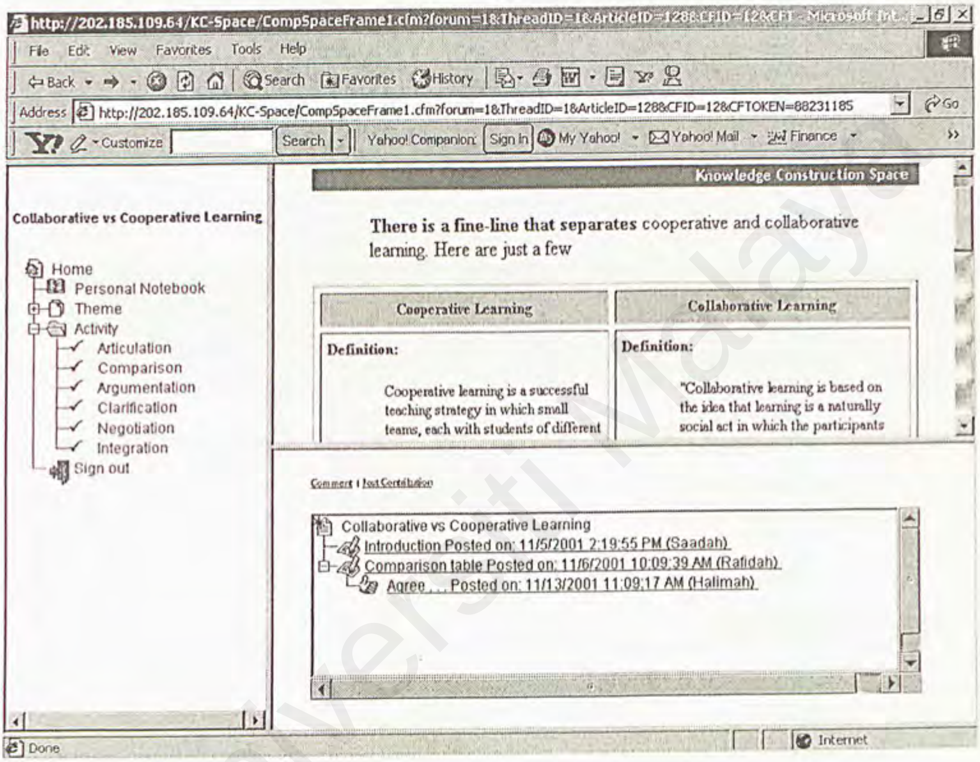

Figure 5.13: Integration Discussion Map

Article Composer. The composer is comprised of two frames (top and bottom) in the same window display. The top frame shows the *Document Explorer* in which articles are displayed as icons in a familiar Explorer-like Windows and can be extracted by simply clicking the icons whereas the bottom frame displays the *HTML Text Editor*. The *Article Composer* provides facilities for users to compose and edit the so-called *Group Reflective Article*, retrieve the others' contribution of elements of article, view the group glossary (see Figure 5.15) and reflect previous thinking from *Negotiation Discussion Map* (see Figure 5.14b).

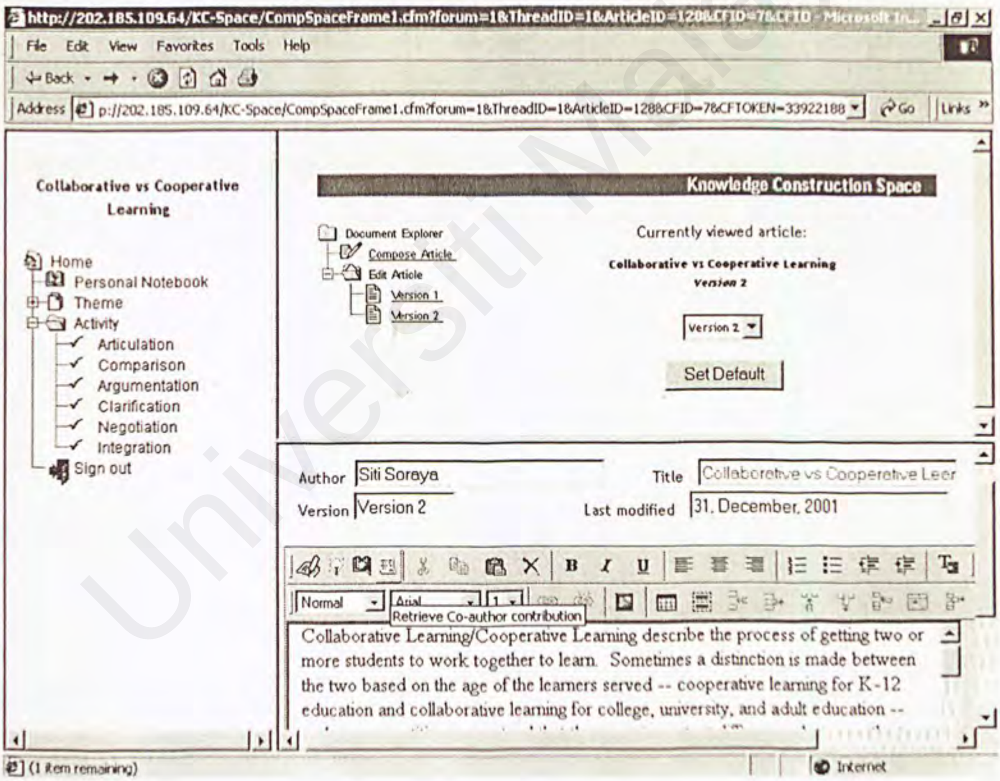

Figure 5.14a: Article Composer

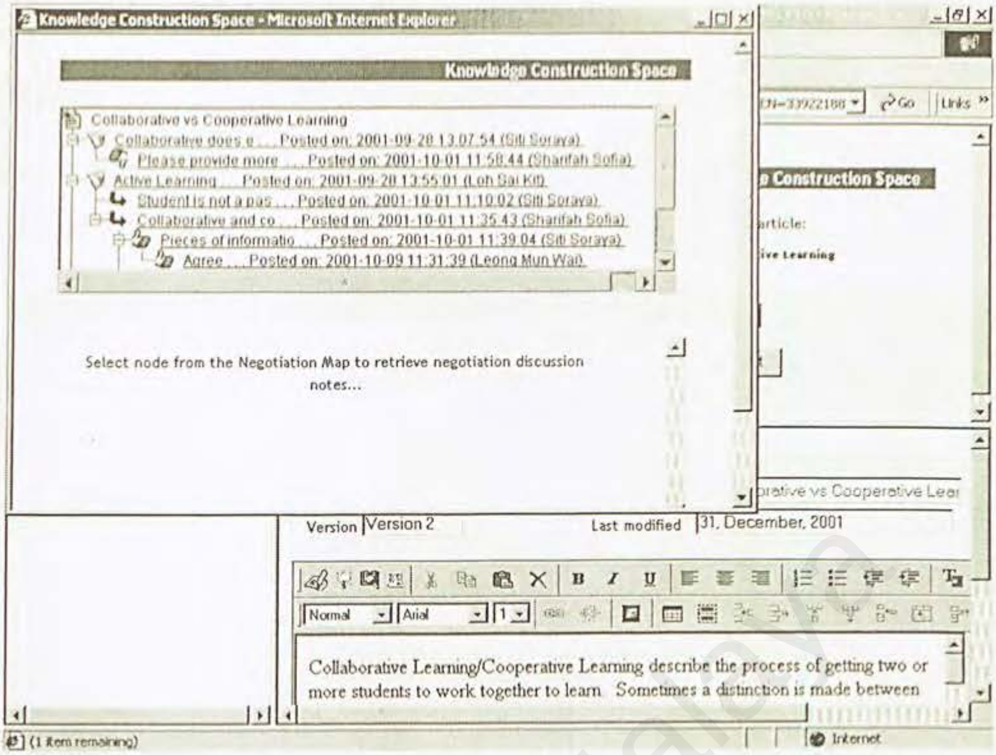

Figure 5.14b: The negotiation discussion map loaded in separate window

Group glossary. This object provides users with the word of list from a shared repository. The users can select an issue from the selection list or search for a specific keyword to retrieve the glossary terms.

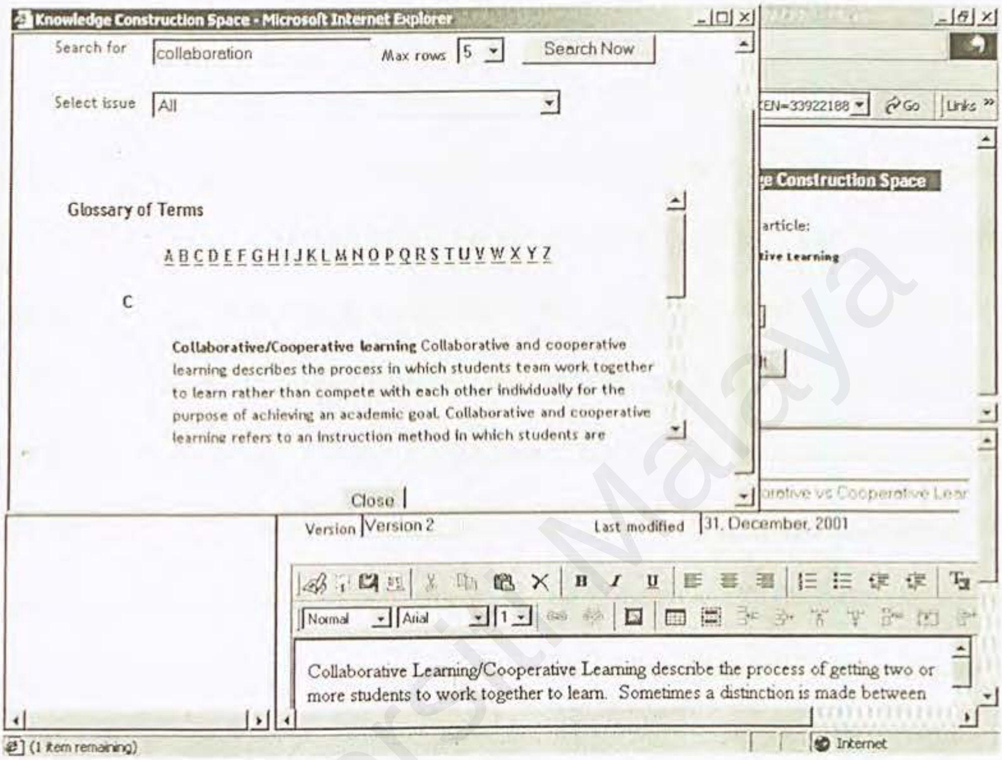

Figure 5.15: Group Glossary

5.2 KC-Space execution

The process starts with the Problem Owner who initiates new discussion by creating new *Issue* or *Theme*, each of which can be considered as a new or sub-issue or as a main theme or a sub-theme respectively. The Problem Owner then creates *The Statement of Issue* to convey the goals and objectives of the discussion and to start each team off with some initial bookmarks links to WWW resources and suggested supporting document. At the end of this process KC-Space generates an emails to notify each member with his/her username, password and KC-Space web address. Team members can then log in to the tool using the pre-mentioned web address. The Problem Owner is the one who is responsible to administer the knowledge construction process and setting up dateline for each activity. Besides, he/she can notify the whole team using KC-Space when important events have taken place. In the *Articulation* phase, team members can view the *Statement of Issue* and then write a *Perspectives Note* using *Articulation Editor*. This phase is performed privately and continues until the specified dateline. Members who were late in posting were considered excluded from the group. However, if the group consists of not more than four members, the Problem Owner can extend the dateline. Upon the Problem Owner decision, the process can be pushed forward to the *Comparison* phase. In this phase team members can then view the whole lists of individual members' differed perspectives from the *Comparator*. The next phase is *Argumentation* where explicit collaboration among team members start off. Team members take part in argumentation discussion where KC-Space maps the arguments allowing members to browse and retrieve all the different perspectives and respond to critics either by arguments to-support or arguments to-object position. KC-Space then display the contents of selected notes in the main window with its attachment of supporting document The supporting documents and external link of other web resources is viewed in separate window other than the main window. Once the Problem Owner decides that the next phase shall start, he/she can send for emails to notify team members that the Clarification phase has started. In the next phase, members take part in *Clarification* discussion dealing with different terminologies of the same construct to form a *Group Glossary*. In the *Group Glossary Window*, a team member is allowed to select the term from the selection lists to summarise the discussion regarding them, which is then called as *Group Glossary*. Once all discussions regarding terms has been summarised and concluded, Problem Owner notify all team members that this phase over and move the process to the following phase. *Negotiation* is the next phase, where members collect, and organize ideas of previous contribution to the discussion and eventually adding this to the *Negotiation Discussion Map*. In this phase, members can specify note he/she wishes to revise from the previous *Argumentation* discussion and compose the so-called *Knowledge Negotiation Note*. The team members can then rate this contribution, each of which should only be rated once. The contribution is considered accepted if more than half of the team members accept it. Otherwise, it is considered rejected. Knowledge construction process ends with the *Integration* phase. In this phase, team members participate in the *Integration* discussion where KC-Space displays the *Integration Discussion Map* that provide mapping discourse of team members who work collaboratively to construct the *Group Reflective Article*. In addition to this, members can write their contribution of element for their group article or provide additional documents by downloading graphic, sound, or video to the list of elements that define the content of article. Only the Problem Owner is granted the right to compose and edit the so-called *Group Reflective Article* using the *HTML Text Editor*. Upon composing the article, the problem owner can retrieve the team members' contribution of elements and copy them to the editor.

5.3 Summary

Two main things were described in this chapter: KC-Space implementation and execution. In the implementation part, the communication infrastructure, the programming language, the database and web server have been described. This has been followed by exploring KC-Space main objects. Each objects has been described, the implementation of its functions has been presented and its graphical representation has been shown where necessary. The final part of this chapter has described the execution of the collaborative knowledge construction process using KC-Space. The different phases, with the main functions briefly presented have been described.

Chapter 6

Evaluation of the KC-Space

This chapter is concerned with the evaluation of the KC-Space with its main lessons learned. Section 6.1 describes the summary of evaluation of the KC-Space and the design of questionnaire. Section 6.2 presents the analysis of responses together with the main lessons learned from the analysis including the comments made by the respondents. Section 6.3 reflects upon the aims, of which the evaluation concerns.

6.1 The evaluation

6.1.1 Pilot study

The primary goal behind carrying out this study is to assess the feasibility of executing the collaborative knowledge construction process using KC-Space. The study is not intended to explicitly address such essential issues as how students construct shared knowledge of the topic or issue, how much sharing is actually achieved among the collaborating partners, and so on. The purpose of the study is to determine:

- The extent to which COKC/KC-Space explicitly address the initial research questions identified in Chapter 1, for example "How to support the students working together in a group to achieve shared knowledge constructed?"
- The rightness of activities for the students to carry out knowledge construction collaboratively.

- The usefulness of various features provided in executing the collaborative knowledge construction process using KC-Space.
- The usability of the KC-Space, for example KC-Space usability design and its overall performance.
- The extent to which KC-Space enhance collaborative learning, individualized learning and student learning through collaborative knowledge construction activities.
- Recommendations and possible enhancements to the KC-Space.

6.1.2 Students

The pilot study involves 8 higher degree students from different academic background (Law, Accounting, Computer Science, Business Administration and Public Administration) who volunteered to participate in the evaluation. The students had no experience in participating collaborative knowledge construction activities before and had no knowledge regarding co-constructions.

6.1.3 Experimental material

For the purpose of evaluation, one article had been prepared. The article, A Definition of Collaborative vs Cooperative Learning (Panitz, T., 1996) serves as the *Statement of Issue* to start the team off with the discussion (see Appendix D).

6.1.4 Environment

The students used PC computers with the specifications ranged from Pentium 11 processor with 32 Megabyte of RAM to Pentium 111 processor with 63 Megabyte of RAM. The KC-Space server was placed in the Human Computer Interaction Lab, University Malaya and the clients was placed at dispersed location, and connected to the server via the Internet. The browser used was the Internet Explorer 4 with Java Applet support.

6.1.5 Methodology

The evaluation consisted of KC-Space training, an experimental material and a written questionnaire. The students were randomly grouped into four, giving a total of two groups. The role of Problem Owner has been represented by the author to tackle with any unexpected problems that might arise using the KC-Space. Each group was provided with half an hour KC-Space training prior to the evaluation session. This was a warm-up task to familiarize the students with the KC-Space facilities, for example Personal Notebook and Group Discussion Map. Two week was required for each group to participate in the evaluation of the KC-Space. Each member in a group was given a questionnaire (see Appendix E). The questionnaire was answered at the end of the evaluation session.

6.1.6 Design of the questionnaire

At the beginning of section 6.1, the purpose of evaluating the KC-Space was clearly defined. Thus the questionnaire was designed in five sections.

- Section one concerns the detail of respondents.
- Section two concerns are two folds:
    - The extent to which COKC/KC-Space explicitly address the initial research questions identified in Chapter 1, for example "How to support the students working together in a group to achieve shared knowledge constructed?"

- The rightness of activities for the students to carry out knowledge construction collaboratively. Twelve questions were asked with a five–point scale of 'extremely frequently, 'quite frequently', 'moderately frequently, 'not very frequently', 'never'.

- Section three concerns the usefulness of various features provided in supporting students in their learning activities. The questions are in a five-point scale of 'extremely useful, 'quite useful', 'moderately useful', 'not very useful', 'not useful'.
- Section four concerns the usability of the KC-Space.
- Section five concerns the general questions on the KC-Space. For example recommendations, opinions, and enhancements to the KC-Space; the extent to which KC-Space enhanced collaborative learning, individualized learning and student learning through collaborative knowledge construction activities.

The complete questionnaire is included in Appendix. E.

6.2 Results of the evaluation and main lessons learned.

Section 2

(a) The extent to which COKC/KC-Space explicitly address the initial research question.

Figure 6.1 summarises the analysis of responses to the questions in Section 2. The line chart clearly shows the frequency distribution of activities for different phases in KC-Space.

The analysis of the proportions of most frequently accessed activities revealed that, students most actively took part in the discussion during the third, forth, fifth and sixth phases of the collaborative knowledge construction process.

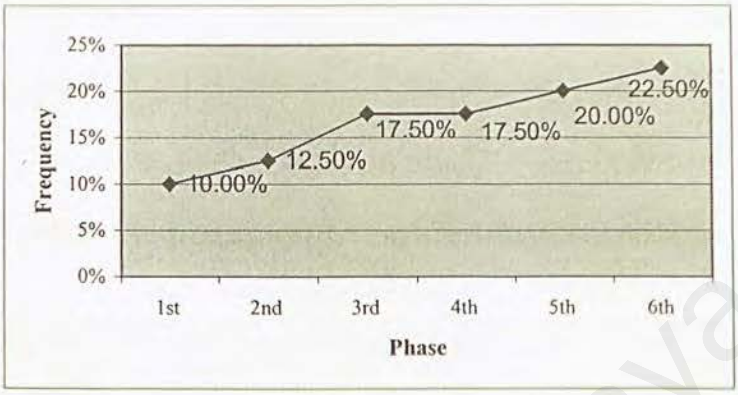

Figure 6.1 Frequency distribution of activities for different phases in KC-Space

The third and forth phase which were for Argumentation and Clarification activities were both 17.50%, followed by 20.00% for Negotiation and 22.50% for Integration during the fifth and sixth phase respectively.

The result shows that the frequency was gradually increased and the activities during Integration phase had the highest frequency during the sixth phase of the collaborative knowledge construction process. This result conveys that the level of collaboration among students increases as students proceed through the various activities from the Articulation phase to Integration phase. This result seems to show the construction of initial research question in accordance with the COKC process model.

(b) Are the activities the right one for the students to carry out knowledge construction collaboratively?

In calculating the mean for questions in Table 6.1, the following scores were used: Extremely frequently = 1, Quite frequently = 2 Moderately frequently = 3 Not very frequently = 4 and Never = 5. Table 6.1 shows the analysis of responses to the questions in Section 2

Table 6.1 Analysis of responses of the collaborative knowledge construction activities

COLLABORATIVE KNOWLEDGE CONSTRUCTION ACTIVITIES	MEAN
Identification/understandings of problem during articulation activities	2.4
Compare alternate viewpoints and its associated arguments during comparison activities	2.1
Summarize glossary contribution	2.8
Reflect and comment on the summarized glossary contribution	2.5
Revise and organize past contribution to the discussion by summarizing, annotating, rephrasing or suggesting new ideas	2.9
Rate the strength, relevance and usefulness of the revised contribution in negotiation activity	2.3
Contribute element that defines the content of the article	2.4
Review and provide comment on the composed article	2.6
Browse past contribution to the discussion from shared repository	2.3
Retrieve group glossary	2.5
Link to suggested sites	2.6
Personal Notebook	2.6

The bar chart of Figure 6.2 summarises the mean scores of these ratings. In order to determine the rightness of activities mean scores are evaluated against the mid-point of 2.5. If mean scores are less than 2.5, then this is considered as correct activities for students to carry out knowledge construction collaboratively, otherwise it is considered inappropriate.

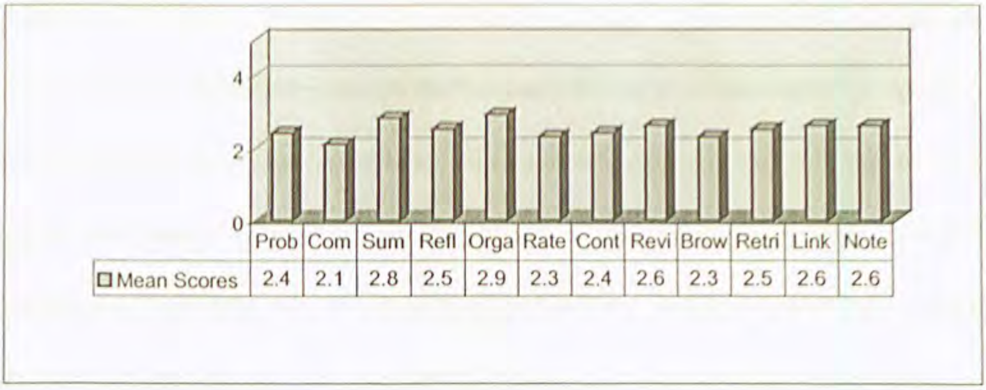

Figure 6.2 An Overview of the Rightness of Activities for collaborative knowledge construction

Pro	**Identification/understandings of problem during articulation activities**	**Con**	**Contribute element that defines the content of the article**
Com	**Compare alternate viewpoints and its associated arguments during comparison activities**	**Revi**	**Review and provide comment on the composed article**
Sum	**Summarize glossary contribution**	**Bro**	**Browse past contribution to the discussion from shared repository**
Refl	**Reflect and comment on the summarized glossary contribution**	**Retr**	**Retrieve group glossary**
Org	**Revise and organize past contribution to the discussion by summarizing, annotating, rephrasing or suggesting new ideas**	**Link**	**Link to suggested sites**
Rat	**Rate the strength, relevance and usefulness of the revised contribution in negotiation activity**	**Not**	**Personal Notebook**

Students did not frequently revise and organise past contribution to the discussion, nor did they summarise the glossary discussion. This conveys that the students found these activities did not really help them in constructing knowledge collaboratively. In addition to this fact, Personal Notebook tool was used by only a fraction of students, thus further work needs to be carried out so as to meet with those problems, seeing that these activities are essential in collaborative knowledge construction.

In addition to the empirical data, subjective responses to the approach were revealing. The following responses from students show that, in at least one instance, KC-Space succeeded in fostering collaborative knowledge construction activities.

"Generally, KC-Space is able to promote knowledge construction collaboratively. The collaborative knowledge construction activities are very helpful in assisting a group of students to share their ideas and simulate new ideas. Most of the activity processes are design in such a way that students can easily understood and follow. For examples, activities such as identification/understandings of problem, comparing alternative viewpoints and its associated arguments, browse past contribution to the discussion from shared repository and link to suggested sites are very common yet useful in collaborative knowledge construction activities. These activities will definitely provide great helps and guides to the students."

Section 3

a) Are the KC-Space features useful to support students in their learning activities?

In calculating the mean for questions in Table 6.2, the following scores were used: Extremely useful = 1 Quite useful = 2 Moderately useful = 3 Not very useful = 4 and Not useful = 5. Table 6.2 shows the analysis of responses to the questions in Section 3

Table 6.2 Analysis of responses of usefulness features provided on the KC-Space

KC-SPACE FEATURES	MEAN
Support the process of expression of ideas	1.6
Viewing and comparing alternate viewpoints	1.5
Organizing/structuring ideas (discussion map)	1.4
Ideas and notions are available for others to comment and argue	1.5
Creation of group glossary	1.8
Provide for knowledge sharing and resolving misunderstandings	1.8
Provide for revision and organization of notes and past contribution to the discussion	2.0
Co-author and the review of the composed article	1.6
Support the process of thinking	1.6
Searchable group glossary and notes of interest	2.1
Support for collaborative knowledge construction	1.8
Provide for social interactions	2.1

The bar chart of Figure 6.3 summarises the mean scores of these ratings. In order to determine the usefulness of various features provided in executing the collaborative knowledge construction process using KC-Space, mean scores are evaluated against the mid-point of 2.5. If mean scores are less than 2.5, then this is considered as useful features, otherwise it is considered of no use.

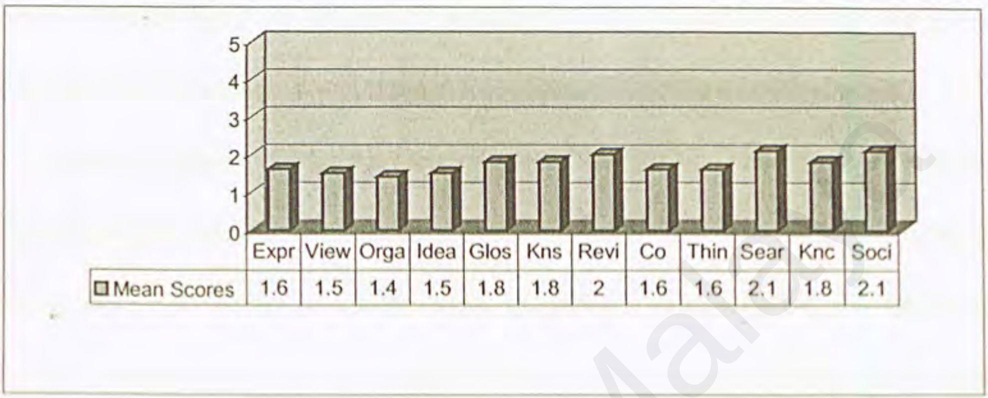

Figure 6.3 An Overview of the usefulness of features provided in KC-Space

Exp	**Support the process of expression of ideas**	**Revi**	**Provide for revision and organization of notes and past contribution to the discussion**
Vie	**Viewing and comparing alternate viewpoints**	**Co**	**Co-author and the review of the composed article**
Org	**Organizing/structuring ideas (discussion map)**	**Thin**	**Support the process of thinking**
Idea	**Ideas and notions are available for others to comment and argue**	**Sea**	**Searchable group glossary and notes of interest**
Glo	**Creation of group glossary**	**Knc**	**Support for knowledge construction**
Kns	**Provide for knowledge sharing and resolving misunderstandings**	**Soci**	**Provide for social interactions**

According to Table 6.2, responses were good for all questions asked. As such, students found that most of the features in KC-Space were useful with an appropriate functionality for them to carry out the tasks. The Group Discussion Map tool had an explicit representation of discourse to lead the group to carry out a discussion efficiently. The students found the Group Discussion Map tool facility useful. Besides, the students found that the availability of ideas and notions for comment was useful and helped them to have an effective decision. The Comparator tool was easy to use and the students regarded the viewing and comparing alternate viewpoints activities as useful.

However, there were some students who found the construction of group glossary features were not easy to use, did not really help them in the decision-making and as such, did not help them to actively contribute in summarising the glossary discussion for term. Student made the following comments: *"I personally feel that the glossary construction part is not an easy accomplished task. Nevertheless, this is an important skill to learn. Besides, the provisions of social interactions and searchable group glossary facilities are not encouraging"*. This conveys that the students found these facilities were not useful in constructing knowledge collaboratively. Further work needs to be carried out so as to comply with those problems given that these facilities were essential in collaborative knowledge construction process.

A number of potential suggestions were also made by the students of what they thought could improve the usefulness KC-Space in term of its facility, for example:

1) Group Discussion Map tool should provide more facilities to help the group to come to an agreement.
2) KC-Space should provide more facilities for creation and completion of projects, problems and other goals.

Students also made the following positive comments on their experience of using the KC-Space in terms of its usefulness of functionality.

"The features in KC-Space are well and adequate in supporting collaborative knowledge construction activities. Most of the features are able to achieve their goals in enabling the collaborative knowledge construction activities to be carried out in groups"

"KC-Space is something interesting for the students to generate ideas and arguments, which could give us the advantage to share effective thoughts. This enable us to view how an issue could be digested in different views, ain't narrow to a point."

"KC-Space is useful to guide thinking on a specific issue, be that as it may, students are required to think creatively themselves as KC-Space is more of an 'analytical thinking' tool."

Section 4

a) Are the KC-Space usability design is acceptable?

Table 6.3 shows the analysis of responses to the questions in Section 4.

Table 6.3 Analysis of responses of KC-Space usability design

KC-SPACE USABILITY DESIGN	MEAN
The page layout and structure helped me to recall the information.	2.5
The page layout was cluttered and hard to read.	2.3
I could easily locate the information I needed.	2.3
Some pages were very slow to load.	3.0
The 'space' is relatively easy to use and navigate.	2.0
The activities were logically organized.	2.1
Frames are used appropriately.	2.1
I found that the knowledge construction environment had a meaningful structure and it supported teamwork.	1.8
The screen layout (white spaces, text, graphics placement) of the page is acceptable.	1.9

The bar chart of Figure 6.4 summarises the mean scores of these ratings. In order to determine the usability of the KC-Space, mean scores are evaluated against the mid-point of 2.5. If mean scores are less than 2.5, then the KC-Space design is considered as usable.

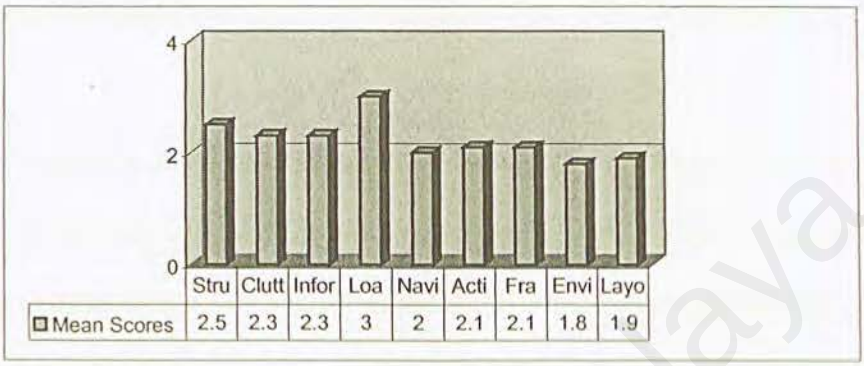

Figure 6.4 An Overview of the usability design of KC-Space

Stru	**The page layout and structure helped me to recall the information.**
Clut	**The page layout was cluttered and hard to read.**
Info	**I could easily locate the information I needed.**
Loa	**Some pages were very slow to load.**
Nav	**The 'space' is relatively easy to use and navigate.**
Acti	**The activities were logically organized.**
Fra	**Frames are used appropriately.**
Envi	**I found that the knowledge construction environment had a meaningful structure and it supported teamwork.**
Lay	**The screen layout (white spaces, text, graphics placement) of the page is acceptable.**

Students were also asked to rate the acceptability of KC-Space usability design. The results conveys that almost all the students agree it is below average with the means answer at 2.5. None of the students stated it is extremely unacceptable. Although few of the students were dissatisfied with the response time, the average was satisfactory.

Generally students were moderately satisfied with KC-Space usability design and its overall performance.

Students also made positive comments on their experience of using the KC-Space in terms of the usability design. The following are examples from the students' opinions:

"Regarding to the usability design, it is quite original and unique. Users who are already familiar to the system can use the system to carry out the collaborative knowledge construction smoothly. However, for the first time users, they may experience little difficulties in using and navigating the system. But once the users get used to the system, then they should be able to use the system to perform their collaborative knowledge construction activities without much difficulties."

"Another aspect to point out is the system process flow design. The system process flow should be complemented. During my testing with the system, I found out that the ways the system design are able to make me to think and to participate actively. It also enables me to communicate easily with the system. Besides, the logical process design is well structured too. However, one little constraints is that first time users must know exactly the system processes before they can fully understand how the system work."

"The representation for the icons used is acceptable and in fact attractive. Overall, interface design is good. It is easy to move around. The flow of the process is well organized."

These comments indicate that attention had been paid to the user interface design of the KC-Space.

In sum, it is clear that the answers to all questions asked are positive. All means scores are below the mid-point of 2.5 except for response time for KC-Space to load page, the means score is 3.0.

Section 5

a) The extent to which KC-Space enhanced collaborative learning, individualized learning and student learning through collaborative knowledge construction activity.

In calculating the mean for questions in Table 6.4, the following scores were used: Strongly agree = 1 Agree = 2 No opinion = 3 Disagree = 4 and Strongly disagree = 5.

Table 6.4 shows the analysis of responses to the questions in Section 5, for example statements for evaluation of extent to which KC-Space enhanced collaborative learning, individualized learning and student learning through collaborative knowledge construction activity.

Table 6.4: Analysis of evaluation to which KC-Space enhanced collaborative learning, individualized learning and student learning through collaborative knowledge construction activity

	MEAN
Collaborative learning groups	1.6
Individualized learning	2.0
Student learning through collaborative knowledge construction activity	1.8

The bar chart of Figure 6.5 summarises the mean scores of these ratings. In order to determine the extent to which KC-Space enhanced (1) collaborative learning, (2) individualized learning and (3) student learning through collaborative knowledge construction activity, mean scores are evaluated against the mid-point of 2.5. If mean scores are less than 2.5, then the KC-Space had generally enhanced the learning activity.

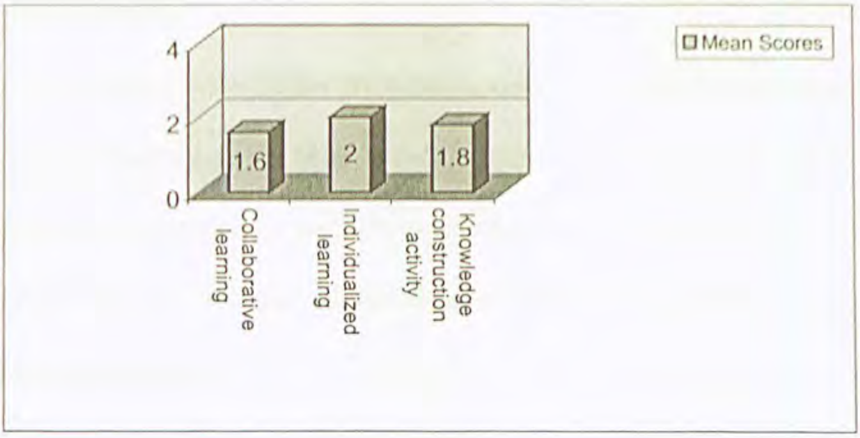

Figure 6.5 An Overview of the extent to which KC-Space enhanced collaborative learning, individualized learning and student learning through collaborative knowledge construction activity

In addition to the empirical data, subjective responses to the approach were revealing. The following response from students shows that, in at least three instances, KC-Space succeeded in fostering:

Collaborative learning

"Knowledge construction is the results of collaborative learning. Students need to make their knowledge explicit to the other, discuss ideas to solve problems and consequently integrate their ideas into "tangible" group product. They need to engage in the group-decision making process, reflect and evaluate on their knowledge and to arrive at a meaningful understanding of other's solutions. The active construction of shared knowledge leads to increase learning and problem solving. In sum, KC-Space had generally addressed the aforementioned activities in promoting knowledge construction, and therefore, of collaborative learning".

Individualized learning

"These are all student control. Suppose there is a shift from previous understanding of individualized learning with the learning materials such as notes and assessment either printed or in multimedia and self paced but still teacher centred in term of the knowledge to the construction of individualized mental model or understanding through peer interactions."

Collaborative Knowledge construction

"KC-Space is quite successful overall in achieving the goal of promoting knowledge construction activities collaboratively."

Finally, the questionnaire includes some free-form comment questions. Students were asked about the KC-Space in general.

"KC-Space offers good activity that help students in growing and developing their mind and thoughts. KC-Space could benefits students in exposing their skill and not by merely reading textbooks. In my opinion, this could be implemented in schools and higher institutions."

6.3 Achievement objectives

The objectives with which the evaluation was concerned were: (see section 6.1.6)

- The extent to which COKC/KC-Space explicitly address the initial research questions identified in Chapter 1, for example "How to support the students working together in a group to achieve shared knowledge constructed?"

- The rightness of activities for the students to carry out knowledge construction collaboratively.
- The usefulness of various features provided in executing the collaborative knowledge construction process using KC-Space
- The usability of the KC-Space
- The extent to which KC-Space enhance collaborative learning, individualized learning and student learning through collaborative knowledge construction activities.
- Recommendations and possible enhancements to the KC-Space

Within these objectives of concern, the major points made were respectively:

- The COKC process model had generally facilitates the process of constructing knowledge collaboratively through both individual and social context so as to achieve shared knowledge.
- The KC-Space had generally found as a viable tool for supporting collaborative knowledge construction.
- Students had generally achieved knowledge sharing between collaborating partners.
- The KC-Space had generally shown good potential as to its rightness of activities for the students to carry out knowledge construction collaboratively
- The students had generally used the various features efficiently when carrying out the tasks
- The features generally had an appropriate functional design for the students to carry out task

- The Group Discussion Map tool had generally found useful for 'mapping' the discourse in a collaborative knowledge construction way.
- The students were moderately satisfied with KC-Space usability and its overall performance
- The KC-Space had generally enhanced collaborative learning, individualized learning and student learning through collaborative knowledge construction activities.
- Suggestions and possible enhancements to the KC-Space had generally been identified.

Consequently, each aim has been achieved although more clear improvements could be made.

6.4 Summary

This chapter has evaluated KC-Space against its requirements. It has described the pilot study conducted for the evaluation process and has examined the results in terms of lesson learned about the feasibility of executing the collaborative knowledge construction process using KC-Space. The next chapter revisits the essential contributions of this research and outlines promising future research directions

Chapter 7

Conclusions and future directions

This chapter is organized into two sections. Section 7.1 concerns the summary of the research. Section 7.2 concerns the research contributions and Section 7.3 presents some topics for future research.

7.1 Summary

The thesis describes and exemplifies a theoretically based approach to the design of collaborative knowledge construction learning environment. It does so by adopting the cognitive constructivism, social constructivism, collaborative learning and Stahl's collaborative knowledge-building theory. It also describes a KC-Space prototype that embodies such a conceptual approach. KC-Space differs from other collaborative knowledge construction systems in several important ways. First, it advocates combining three main learning theories: cognitive constructivism, social constructivism, collaborative learning and partly from Stahl's collaborative knowledge-building theory. Second, it defines an explicit process model of collaborative knowledge construction, named COKC apart from CLARE. Third, it implements explicit representations of group discussion which provides mapping discourse in a collaborative knowledge construction way. Forth, KC-Space is designed to support more general-purpose collaborative knowledge construction learning environment. Fifth, it provides computer support for closing the collaborative knowledge construction loop per Stahl's theory focusing as much on ending up with one collaborative piece of work. An analysis of experimental data confirms that KC-

Space is the learning environment that fosters collaborative knowledge constructions. This shows that COKC process model provide useful process level to guide students through the knowledge construction process collaboratively. In addition, analysis also reveals a number of issues for further research.

7.2 Main contributions

The research has made the following three major contributions.

1. It defines an approach to learning that engages the student in tasks, which facilitate collaborative knowledge construction. In addition to this, it defines an explicit COKC process model to assist students in constructing knowledge collaboratively through both individual and social context.
2. It provides a theory-based, collaborative knowledge construction learning environment called KC-Space that integrates COKC process model, an instrumentation mechanism.
3. It describes evaluation of experiments that provide useful empirical insights on the feasibility of executing collaborative knowledge construction process using KC-Space. They also provide a rich data source for guiding further development of KC-Space and future experimentation on collaborative knowledge construction in general.

The subsequent sections elaborate on each of these contributions.

7.2.1 Collaborative knowledge construction

The contribution of this research at this level is twofold. First, it attempts to bridge the gap between the recent development in the theories of learning and the advancement in information and communication technologies (ICT) to promote technology-mediated higher education (Kanuka, Heather & Anderson, Terry, 1999). It does so by adopting three main learning theories: cognitive constructivism, social constructivism, collaborative learning and partly from Stahl's collaborative knowledge-building theory as its conceptual basis and providing a computer-supported learning environment, which focuses on collaborative knowledge construction. Second, the research defines what the collaborative knowledge construction is by providing an explicit process model called COKC, which specifies the six key learning activities. Moreover, it also provides KC-Space learning environment that integrates COKC process model.

7.2.2 Design and implementation of the KC-Space

The contribution of KC-Space reside in the following features:

1. KC-Space is grounded in a well established learning theories namely, cognitive constructivism, social constructivism, and collaborative learning as well as Stahl's collaborative knowledge-building theory.
2. KC-Space is an evaluable system. KC-Space was designed to support empirical experimentation on collaborative knowledge construction.

7.2.3 Empirical evaluation of KC-Space

An experiment was conducted as part of the KC-Space evaluation. Specifically, these experiments provide evidence in support of the following claims:

- COKC process model facilitates collaborative knowledge construction through both individual and social context so as to achieve shared knowledge.
- KC-Space is a viable tool for supporting collaborative knowledge construction.
- KC-Space provides a useful means of allowing students to achieve knowledge sharing amongst collaborating partners.
- The group discussion map are found useful for 'mapping' the discourse in a collaborative knowledge construction way.
- The KC-Space had shown good potential as to its rightness of activities in meeting the characteristics exhibited by three main theories of learning: cognitive constructivism, social constructivism and collaborative learning.
- The KC-Space features had an appropriate functional design for the students to carry out the tasks
- The students had used the KC-Space features efficiently when carrying out the tasks
- The students were satisfied with KC-Space usability and its overall performance

7.3 Future research

This research has raised more questions than it has answered. Some basic questions it has raised are for example:

- Does students construct a shared mantel model of issue or topic after collaboration? If so, how? How much sharing is actually achieved between collaborating students?

- Does the extent of knowledge co-constructed between collaborating students result in improved understanding of the issue or topic they are working on? In other words, do students who construct knowledge collaboratively tend to understand the issue or topic more as a result of collaboration?

To answer these and many other similar questions require a more robust KC-Space, new and better theoretical explanations as well as additional experimentation. The purpose of this section is to suggest several ways in which COKC process model and KC-Space can be enhanced, and more rigorous experiments can be performed. The subsequent section identifies a number of immediate enhancements to KC-Space. Most of these extensions are direct response to the findings from the evaluation experiments. The section is organized into three parts: COKC process model, KC-Space, and experimentations.

7.3.1 COKC process model

1. *Context.* While it mainly focuses on the context of higher education, its idea could also be applicable to other educational instances as long as the specific conditions of those learning contexts are taken into considerations.
2. *Collaborative writing.* COKC process model was not designed to explicitly support collaborative writing tasks. Nevertheless, certain aspects of collaborative writing can benefit from the COKC approach. First, COKC can be used as process model for collaborative authoring. Second, some of the COKC suggested tools, such as group discussion map and notebook may serve as tools appropriate for such purposes.

In spite of this potential, KC-Space needs to be further extended at the computational level so as to provide support for collaborative writing tasks. Hence, further work is needed to explore the effectiveness of the introduced COKC process model to meet the above-mentioned extensions.

7.3.2 KC-Space

The following features are incremental extensions to the current version of KC-Space.

1. *Enhancements in the maintainability, expandability and robustness of KC-Space:* Initially, KC-Space was intended as prototype to show a proof of concept of how such collaborative knowledge construction support tools can be built, and are not necessary robust or bug-free. A further enhancement will need to be extended to provide the following capabilities:
   - To make the KC-Space robust.
   - To make the KC-Space easy to update, maintain and expand.
2. *Enhancements in the reliability and performance:* One major step in this direction is to upgrade KC-Space to use the most recent versions of Cold Fusion Application Server of which have improved reliability and performance.
3. *Improvement to the KC-Space interface.* KC-Space needs to move toward a complete graphical interface similar to existing systems such as KIE and Web Knowledge Forum.
4. *Deadlock discussion.* KC-Space should provide more facilities for the students to end any deadlock discussions.

7.3.3 Experimentation

At an empirical level, there are two limitations in the design and execution of the KC-Space evaluation experiments:

1. *Improper selection of Issue.* The issue 'A Definition of Collaborative vs. Cooperative learning' (Panitz, T., 1996) used in the experiment was considered as too difficult because they was not chosen to meet the level of knowledge of students. Moreover, the students had no experience in participating collaborative knowledge construction activities before.
2. *Improper training* as each group was provided with half an hour KC-Space training prior to the evaluation session. Furthermore, the students were the first time KC-Space users.
3. *Less-than-intuitive* interface to the novice users.

The following recommendations will help lead to better KC-Space experimentation.

1. *Careful selection of Issue.* The selection of 'Issue' used, as experimental material needs to be carefully weighted according to the students' level of knowledge.
2. *Training and pilot testing.* Adequate training must be given prior to session. A series of task scenarios is an additional aid to assist students to carry out the pilot testing
3. *True experimental design.* Pre- and post-tests are conducted when necessary. Learning outcomes are measured quantitatively. Quantitative measurements include the different metrics collected from the experiments.

KC-Space is till in an early stage of evolution. Hence, the lessons learned from the experiments are of particular importance, for they form a basis on which future work will be performed. Uncovering the above problems is an important part of the contribution of this research.

References

A. Gokhale (1995). *Collaborative Learning Enhances Critical Thinking.* Journal of Technology Education, Volume 7, Number 1, Fall 1995.

Ausbel, D.P. (1963). *The Psychology of Meaningful Verbal Learning.* Grune & Stratton, 1963. In Wan, D., & Johnson, P.M. (1994).

Bannon, L., (1989). *Issues in Computer-Supported Collaborative Learning.* Chapter to appear in Proceedings of NATO, Advanced Workshop on Computer-supported Collaborative Learning, September 1989, Maratea, Italy.

Bell, P., Davis, E.A., & Linn, M.C. *The Knowledge Integration Environment: Theory and Design.* [online]. Available: http://www.kie.berkeley.edu/KIE. Retrieved: May 27, 2000.

Berger & Luckman. (1996) *The Social Construction of Reality: a Treatise in the Sociology of Knowledge,* Doubleday, 1996. In Wan, D., & Johnson, P.M. (1994).

Blanchette, J. & Kanuka, H. (1999). *Applying constructivist learning principles in the virtual classroom.* Proceedings of Ed-Media/Ed-Telecom 99 World Conference , June 1999, Seattle, WA. In Kanuka, Heather & Anderson, Terry (1999).

Bouton, C., & Garth, R.Y. (1983). *Learning in Groups* (New Directions in Teaching and Learning, No. 14). San Fransisco: Jessey-Bass. In Hiltz, S.R. (1995).

Brown, J.S., Collins, A., & Duguid, P. (1989). *Situated Cognition and Culture of Learning.* Educational Researcher, 18:32-41. In Coppola, N., Rana, A., & Bieber, M. (1997).

Bruffe, K.A. (1986). *Background and History to Collaborative Learning in American Colleges.* College English, 46(7), 635-652. In Hiltz, S.R. (1995).

Carey,S. (1985). *Conceptual Change in Childhood.* Cambridge, MA: MIT Press. In Bell, P., Davis, E.A., & Linn.

Charles Y.Y. Cheng & Jerome Yen (1998). *Virtual Learning Environment (VLE): A Web-Based Collaborative Learning System.* Proceedings of the 31st Hawaii International Conference on System Sciences (HICSS'98), published by the IEEE Computer Society.

Cognition and Technology Group at Vanderbilt (1993). Anchored instruction and situated cognition revisited. *Educational Technology, 33(3),* 52-70. In D.Hsiao.

Collins, A., Brown, J.S., & Newman, S.E. (1989). *Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics.* In Fishman, B. et al's (1997).

Coppola, N., Rana, A., & Bieber, M. (1997). *Collaborative Hypermedia Educational Framework (CHEF): Instruction and Assessment of an Instructional Model.* AusWeb97, 3rd Australian World Wide Web Conference.

Dewey, J. (1959). *Dewey on Education. Selections from the Child and the Curriculum.* Teachers College Press, New York. In Coppola, N., Rana, A., & Bieber, M. (1997).

D.Hsiao. *The CSCL Theories.* [online] Available: http://www.edb.utexas.edu/csclstudent/Dhsiao/theories.html Retrieved May 23, 2000.

Dillenbourg, Pierre & Schneider, Daniel (1995). *Collaborative Learning and the Internet* [online] Available: http://tecfa.unige.ch/tecfa/research/CMC/colla/iccai95_1.html Retrieved April 15, 2000.

diSessa, A (1993). *Toward an Epistemology of Physics. Cognition and Instruction,* 10(2-3), 105-225. In Bell, P., Davis, E.A., & Linn.

Doolitle, P.E. (1998). *Integrating Constructivism and Cognitivism.* Paper presented at the 9th International Conference on College Teaching and Learning, Jacksonville, FL, April 18, 1998.

Driscoll, M.P. (1994). *Psychology of learning for instruction.* Toronto, ON: Allyn and Bacon. In Kanuka, Heather & Anderson, Terry. (1998).

Edelson, D.C., Pea, R.D., & Gomez, L. *Constructivism in the Collaboratory.* To appear in B.G. Wilson (1995) Constructivist Learning Environments: Case Studies in Instructional Design. Eaglewood Cliffs, NJ: Educational Technology Publications.

Farquhar, J., (1995). *The Internet as a Tool for the Social Construction of Knowledge.* In Charles Y.Y. Cheng & Jerome Yen (1998).

Fishman, B. et al's (1997). *The CoVis Project: A National Testbed for Science Learning Reform.* An Interactive Poster Session, NARST 1997, Oak Brook, IL.

Fosnot, C.T. (1996). *Constructivism: Theory, perspectives, and practice.* New York: Teachers College Press. In Doolitle, P.E. (1998).

Hiltz, S.R. (1995). *Teaching in a Virtual Classroom*: 1995 International Conference on Computer Assisted Instruction ICCAI'95. National Chiao Tung University, Hsinchu, Taiwan. March 7-10, 1995.

Johnson, David W. (1981). *Student-student Interaction: The Neglected Variable in Education.* Educational Research (pp. 5-10). In Hiltz, S.R. (1995).

Johnson, D.W., & Johnson, R.T. (1975). *Learning Together and Alone: Cooperation, Competition, and Individualization.* Englewood Cliffs, NJ: Prentice Hall. In Hiltz, S.R. (1995).

Jonassen, D.H, Davidson. M., Collins, M., Campbell, J. & Haag, B.B. (1995). *Constructivism and computer-mediated communication in distance education*. The American Journal of Distance Education, 9(2), pp. 7-26.33.

Jonassen, D.H. (1994) *Technology as Cognitive Tools: Learners as Designers*. Unpublished paper on ITForum mailing lists. [online] Available: http://itech.coe.uga.edu/itforum/paper1/paper1.html Retrieved: May 27, 2000.

Jonassen, D.; Mayes, T; and McAleese, R. (1993). A manifesto for a constructivist approach to uses of technology in higher education. In T.M. Duffy; J. Lowyck; and D.H. Jonassen (Eds.), Designing environments for constructive learning. Heidelberg, Germany: Springer-Verlag Berlin. [online] Available: http://cad017.gcal.uk/clti/papers/TMPaper11.html Retrieved: May 27, 2000.

Jonassen, D.H. (1991). *Objectivism vs. constructivism: Do we need a philosophical paradigm shift?* Educational Technology: Research and Development, 39 (3), 5-14.

J.W. Alba & L. Hasher (1983). *Is Memory Schematic?* Psychological Bulletin, 93:203-31, 1981. In Wan, D., & Johnson, P.M. (1994).

Kanuka, Heather & Anderson, Terry. (1999). *Using Constructivism in Technology-Mediated Learning: Constructing Order out of the Chaos in the Literature*. Radical Pedagogy: 1, 2 [online] Available: http://www.icaap.org/iuicode?2.1.2.3. Retrieved May 9, 2000.

Kanuka, Heather & Anderson, Terry. (1998).*Online Social Interchange, Discord, and Knowledge Construction*. Journal of distance education.

K.D. Knorr-Centina. *The Manufacture of Knowledge: an Essay on the Constructivist and Contextural Nature of Science*. Pergamon Press, Oxford, 1981. In Wan, D., & Johnson, P.M. (1994).

Klemm, W.R. & Snell, J.R. (1995). *Instructional Design Principles for Teaching in Computer Conferencing Environments*. [online]. Available: http://www.cvm.tamu.edu/wklemm/instruct.html. Retrieved May 21, 2000.

Koschmann, T. (Ed). (1996). *Paradigm Shifts and Instructional Technology. CSCL: Theory and Practice of an Emerging Paradigm*. Mahwah: Lawrance Erlbum Associates.

Kreijns. K & Kirschner. P.A. (2001). *The Social Affordances of Computer-supported Collaborative Learning Environments*. 31[th] ASEE/IEEE Frontiers in Education Conference, October, 2001, Reno, NV.

Lehtinen. E., Hakkarainen. K., Lipponen. L., Rahikainen. M., Muukkonen. H. (1999) *Computer Supported Collaborative Learning: A Review*. [online]. Available: http://www.kas.utu.fi/papers/clnet/clnetreport.html#_Toc450628938. Retrieved: April 4, 2000.

Liflander Veli-Pekka (1999). *Expansive Knowledge Construction in Network-based Project Learning*. Enable99, Enabling Network-based Learning Conference.

Linn, M.C. (1995). *Designing Computer Learning Environments for Engineering and Computer Science: The Scaffolded Knowledge Integration Framework*. Journal of Science Education and Technology, 4(2), 103-126. In Bell, P., Davis, E.A., & Linn, M.C.

Linn, M.C., Songer, N.B., & Eylon, B.S. (in press). *Shifts and Convergences in Science Learning and Instruction*. In Bell, P., Davis, E.A., & Linn, M.C.

Neil Stillings, Mark Feinstein, Jay Garfield, E.L. Rissland, D.D. Rosenbaum, S.E. Wiesler, & L.Baker-Ward (1987). *Cognitive Science: an Introduction*. MIT Press, 1987. In Wan, D., & Johnson, P.M. (1994).

Novak, J.D., & Gowin, D.B. (1984). *Learning How to Learn*. Cambridge University Press. In Wan, D., & Johnson, P.M. (1994).

Pea, R.D. (1994). *Seeing What We Build Together: Distributed Multimedia Learning Environments for Transformative Communications*. Journal of the Learning Sciences. In Edelson, D.C., Pea, R.D., & Gomez, L.

Pfister, H.-R., Wessner, M., Holmer, T., Steinmetz, R. (1999). *Negotiating about Shared Knowledge in a Cooperative Learning Environment*. [online]. Available: http://learninglab.stanford.edu/CSCL99/papers/monday/pfisterwessnerS93.html Retrieved: 23 May, 2000.

Piaget, J. (1970). *The Science of Education and the Psychology of the Child*. N.Y: Grossman.

Rachel. E. Scott., (2000). *Constructivist pedagogy for Social Studies Education: Meeting the National Council for the Social Studies Standard*. [online]. Available: http://filebox.vt.edu/users/rratliff/Electronic%20portfolio/construct.pdf

Resnick, L.B. (1983). *Cognition and Instruction: Issues and Agendas*. Hillsdale, NJ: Lawrance Erlbum Associates. In Bell, P., Davis, E.A., Linn, M.C.

Salo, P. (2001). *An individual's contribution to the networked collaboration*. A paper presented in TECFA Workshop, September, 2001, Sonloup, Switzerland.

Salomon, G. (1992). *What does the design of effective CSCL require and how do we study its effects?* Proceedings of 1992 ACM Conference on Computer Supported Collaborative Learning.

Scardamalia, M. & Bereiter, C (1994). *Computer Support for Knowledge-building Communities*. The Jounal of the Learning Sciences, 3(3), 260-283.

Scardamalia, M., Bereiter, C., McLean, R.S., Swallow, J., & Woodruff, E. (1989). *Computer-supported Intentional Learning Environments*. Journal of Educational Computing Research, 5(1), 51-68.

Spiro, R. J., Coulson, R.L., Feltovich, P. J., and Anderson, D. K. (1988). Cognitive flexibility: Advanced knowledge acquisition ill-structured domains. In proceedings of the Tenth Annual Conference of Cognitive Science Society, Erlbaum, Hillsdale, NJ, pp.375-383. In D.Hsiao.

Stahl.G., (2000). *A model of a Collaborative Knowledge Building*. [online] Available: http://www.cs.colarado.edu/~gerry/publications/conferences/2000/icls/index.html. Retrieved: June 9, 2000.

Panitz, T. (1996). A Definition of Collaborative vs Cooperative Learning. [online]. Available: http://www.lgu.ac.uk/deliberations/collab.learning/panitz2.html Retrieved: 27 July, 2000.

Tudge, J. & Rogoff, B. (1989) *Peer Influences on Cognitive Development: Piagetian and Vygotskian Perspectives*. In Coppola, N., Rana, A., & Bieber, M. (1997).

Vosniadou, S, & Brewer, W.F. (1992). *Mental Models of the Earth: A Study of Conceptual Change in Childhood*. Cognitive Psychology, 24(535-558). In Bell, P., Davis, E.A., & Linn, M.C.

Vygotsky, L. (1978). *Mind in Society*. Cambridge, MA: M.I.T. Press.

Wan, D., & Johnson, P.M. (1994) *Computer Supported Collaborative Learning Using CLARE: the approach and experimental findings*. Proceedings of 1994 ACM Conference on Computer Supported Cooperative Work.

Wiburg, K.M. (1995). *A Historical Perspective on Instructional Design: Is it Time to Exchange Skinner's Teaching Machine for Dewey's Toolbox?* Proceedings of the Computer Supported Cooperative Learning Conference, 1995.

Whipple, W.R., (1987). Collaborative learning: Recognizing it when we see it. *Bulletin of the American Association for Higher Education*, 40, (2), 3-7. In Hiltz, S.R. (1995).

W. R. Klemm (1994). *Using a Formal Collaborative Learning Paradigm for Veterinary Medical Education*. Journal of Veterinary Medical Education, Volume 21. Number 1, Spring 1994.

Knowledge Forum. [online]. Available: http://csile.oise.utoronto.ca Retrieved: 7 June, 2000.

Appendix F: List of publications

Abdul Rahman, S.S. (2002). *Web-based Collaborative Knowledge Construction Space*. Bengkel Tahunan Biasiswa National Science Fellowship (NSF) 2001, 14 - 15 January 2002, Kuala Lumpur.

Salim, S.S., Abdul Rahman, S.S., Nasaruddin, F.H. (2001). *A Process Model For Supporting Collaborative Knowledge Construction Activities For Learners*. Malaysian Science and Technology Congress 2001, 8 – 10 November 2001, Penang.