Online Education: A Learner-Centered Model with Constructivism

Kam Hou VAT

Faculty of Science & Technology

University of Macau, Macau

fstkhv@umac.mo

This paper describes the initiative to construct a WWW-enabled course and project support environment for undergraduate education, aimed to uphold the constructivist's ideas of active learning. The system is intended to create learning experiences that invite students to construct knowledge and to make meaning of their worlds of learning. In particular, we discuss the educational framework of our design through the Problem-Based Learning (PBL) approach, from the perspectives of the architect of the intellect. We also describe the incremental prototyping process of software development, through scenarios of participatory design of our students in Software Engineering at the author's affiliated faculty. The paper concludes by discussing the challenge of implementing the fully functioning constructivist WWW-based environment through blending the art and science of teaching into creative cognitive designs.

Keywords: **Constructivism**, **Problem-Based Learning (PBL)**, **Learner-Centered Philosophy**

1 Introduction

With the advent of the World Wide Web (WWW or Web) towards the end of the 20th Century, the use of this Internet-based hypermedia technology in education has become the trend of today. The Web is aimed to facilitate learning in different disciplines, and is becoming the major driver to construct numerous experimental Web-based support environment in campuses around the globe. However, online education in the form of Web-based instructions (WBI) or Web-enabled learning environment, without an anchoring philosophy of education, could easily become a technology-rich educational wasteland. The theme of this paper is to investigate how the insights of our educational visionaries [5] could be designed into our Web-based support environment, to suit the unique schemata of individual learners. Actually, such designs require rigor in identifying certain essential elements of the constructivist architecture. And they represent challenges to the learning in our daily classrooms, which has typically involved having students repeat newly presented information on tests or in reports. Constructivist teaching practices help learners internalize, or transform new information, which in turn makes further understanding possible. Therefore, as instructional designers, the guiding question in tackling our Web-based design is this: How do we create a technology-enhanced learning environment that engages students in the types of activities that will take on their initiative and responsibility for their own learning?

2 Project Background

In the spring of 1999, a group of junior students in Software Engineering, initiated an informal study group (ISG) [15] with the author's facilitation. The ISG's mission is to help students develop their team-based technical interest in preparation for their graduation project. And we started exploring the ongoing development of Web-based distributed applications with online education as one of our first discussion topics. During the discussion, the author, as an instructor, expressed his difficulties in traditional classroom setting, to recognize students' intellectual and motivational problems, to explain to them a difficult part of the subject matter, to provide clear tasks, and to coach students in specific problem-solving activities. These issues indeed go far beyond the classroom walls. As students, they expressed their need for a learner-centered atmosphere whose focus is put on the needs, skills, and interests of the learners, and whose goal is to encourage active exploration and construction in the course of learning activity. Likewise, we developed the initial idea of creating an environment where anyone is free to learn, to construct and refine new meaning in one's own learning, and to have enough channels to ask for help, when necessary, in the form of some extended service of a good teacher. We continue our expedition into Web-based technology to turn out the project ideas of creating a) a course support environment for active learning, and b) a project support environment for problem-based learning (PBL). The former has been given the project name **REAL** [13] to imply a Rich Environment for Active Learning, while the latter, **SUPER** [14] to denote SUitable and Practical Educational Resources for group-based project work. And in either project, we have not ruled out the familiar face-to-face classroom interactions between teacher and students, as one of the essential aspects of the learning process.

3 Pedagogical Intakes

In selecting the pedagogy of our Web-based environment, we have borrowed from the legacies of our educational visionaries in blending the art and science of constructivist teaching. John Dewey's designs embedded learning in experience [3]. He advocated field studies and immersion in experiences to stimulate learning. Jean Piaget's work influences constructivist educators through designs of discovery learning [9]. Students manipulate subject matter and objects representing the subject matter as they interpret their findings. He believed that learners' internalization leads to structural changes in how they think about something as they assimilate incoming data. Today, constructing meaning on the basis of one's interpretation of data is the heart of science inquiry, problem-based learning models, and case studies. Lev Vygotsky's theory [16] suggests that we learn first through person-to-person interactions and then individually through an internalization process that leads to deep understanding. This belief in the social process of idea making permeates today's interactive classroom led by skillful teacher questioning. Reuven Feuerstein's mediated learning theory [4] refutes the concept of an unchanging intelligent quotient (IQ) and leads to intense examination of how the classroom affects students' metacognition. He believes that the discovery process requires intervention from the teacher to guide learning. On examining the varied work of the master architects, and trying to crystallize the essential elements of the constructivist architecture, we see an array of tools emerging. They include a learner-centered curriculum; enriched environments; interactive settings; differentiated instruction; inquiry, experimentation, and investigation; mediation and facilitation; and metacognitive reflection.

4 Instructional Design

We expect the instructional design of our Web-based support should increase student participation and communication through re-designing the delivery of college lectures to incorporate more student online activities and instructor's feedback before, during and after the contact session. The environment is expected to develop students' abilities to generate problems, to engage in collaboration, to appreciate multiple perspectives, to evaluate and to actively use knowledge. From the designers' standpoint, we have included the following enabling ideas:

a) *Enable students to determine what they need to learn through questioning and goal setting.* It is believed that students should work to identify their knowledge and skill deficits, and to develop strategies in the form of personal learning goals for meeting those deficits. The emphasis is to foster a sense of students' ownership in the learning process. If teachers, through the Web-based support environment, can guide the students in identifying what they already know and what they need to learn, then knowledge gaps and mistakes can be viewed in a positive way such as another opportunity to learn. And students can assume more responsibility in addressing their own learning needs during any instructional unit.

b) *Enable students to manage their own learning activities.* It is believed that students should be enabled to develop their learning plans, which should describe priorities, instructional tactics, resources, deadlines, roles in collaborative learning situations, and proposed learning outcomes, including presentation and dissemination of new knowledge and skills, if applicable. Traditionally, these instructional events are arranged by teachers to be obeyed by students, in order to accomplish a specified set of pre-determined objectives. Yet, it is not advantageous for students to learn to be self-directed. To manage their own learning activities, students must be guided and supported by the teacher, through the Web-based environment, slowly taking on more and more responsibility of their own learning.

c) *Enable students to contribute to one another's learning through collaborative activities.* It is believed that students should be encouraged and supported to discuss and share their personal findings. Particularly, we should enable students to become co-builders of the course/learning resources through evaluating and refining the entries their peers put into the Web-based depository. Collaborative group-based learning seems appealing to achieve the purpose. Students, nevertheless, must be educated to recognize what they are trying to learn in group-work, value it, and wish to share that value with others. Teachers can provide this sense of accountability and belonging by structuring students' work in the support environment with such concept as computer-supported cooperative work (CSCW).

It is convinced that the efficacy of the learning environment is a function of many complex factors, including curriculum, instructional methodology, student motivation, and students' developmental readiness. Trying to capture this complexity onto the design of our Web-based environment, is more an ongoing iterative process than a one-time activity. So we develop scenarios of situated learning support applicable to both individual course taking and group-based project work. These scenario-based supports are then incorporated into the environment incrementally, subject to our students' participatory testing.

5 Scenario-Based Support

Imagine attending a class where the instructor, after giving an introduction of what the course is entailed, invites you to visit his/her course support environment on the Web. On entering the Web-based environment, you are offered the privilege of creating your own personal space in the form of a customizable Web page guarded by your self-assigned identifier and password. Within your personal Web space, you are furnished with some tools to start your Web-life. These include a communications facility to keep one another in touch (email and newsgroup); a calendar planner to track your appointments or commitments (meetings or homework due dates, or project deadlines); and a frequently-asked-questions (FAQ) tool to send for instructor's help when encountering difficulty in housekeeping the personal space. Also, there are pathways to other service modules:

a) *Course Information.* This module provides such information as the course description, pre-requisite requirements, evaluation policy, references list, and other details such as time and location of the lectures. It also includes links to the instructor's contact details, his/her teaching/research profile, and the course schedule showing timetable for class with links to the study materials before, during and after contact sessions. Also included is the announcement service representing the most up-to-date information sent to the students from the instructor.

b) *Course Resources.* This module comprises the study materials prepared by the instructors, and the contributions representing students' submitted or reported work of interest to other students. Study materials can further be cataloged and managed as different resources: study notes, tutorial handouts, supplementary lecture details, or Web-links in the Internet. It could also include FAQs of the course: homework, quiz's, tests, examinations, and projects.

c) *Course Assessment.* This module keeps track of students' performance. The score each student obtained after completing a specific activity is recorded with enough details for evaluation at the end of the course. Students are encouraged to propose their own study plan to earn the accumulated score required, to complete the course. This service is designed into the Learning Contract [7] component to individualize the learning process for any individual learner. Typically, a student is required to write a formal agreement, which details what will be learned, how the learning will be accomplished, the period of time involved, and the specific evaluation criteria to be used in judging the completion of the learning.

d) *Course Inquiry.* This module fulfills several requirements of the teacher-student inquiry interaction. These include: a) a sense of dedicated space for an extended collaboration between teacher and student; b) an incremental delivery of inquiry results from teacher to student; and c) visibility of the inquiry interactions to avoid duplicating effort, and to encourage discovery of related interests. When an inquiry is initiated by a student, a request Web page is generated which is specific to that interaction and to which the teacher and student return frequently for their interaction. This request Web page (meeting space on the Web), contains the relevant material required for the specific inquiry interaction, say, contact details of the student and the teacher in the form of Web links or email addresses. Each request Web page supports several types of interaction: posting comments, recording actions, uploading/downloading files. These can be carried out at any time in any order. This feature is designed to support the often-time extended discussion and incremental result delivery of the teacher-student collaboration. Also, since the completed request Web page could be visible to any registered student or teaching staff within the Faculty intranet, this increases the general awareness of the teacher's activities in consulting students, and avoids duplicating efforts of other staff in dealing with similar questions from students. More importantly, when users browse the inquiry activities over the Web, they are always exposed to information as to who was involved in what, and eventually they will learn about one another's specialties and interests. Hopefully, they will form communities centered about specific knowledge and interest; such are considered as important assets of any educational institute.

Now, on visiting the Web-based support environment and reading the latest announcement for the next lesson, you are aware that the next lesson is about group-based project work. According to the instructor's message, group project work is an essential component of any academic degree; many professional societies worldwide emphasize project and group work as preparation for professional practice. Also, you are to follow the problem-based learning (PBL) approach to work in teams. And you will be introduced to the teaming process and the PBL support of the Web-based environment.

6 Problem-Based Learning (PBL)

It is understood that project work is recognized as having many educational and social benefits, in particular providing students with opportunities for active learning. However, teaching, directing and managing group project work is not an easy process. This is because projects are often: *expensive* demanding considerable supervision and technical resources; and *complex* combining design, human communication, human-computer interaction, and technology to satisfy objectives ranging from consolidation of technical skills through provoking insight into organizational practice, teamwork and professional issues, to inculcating academic discipline and presentation skills. In preparing our students to get started with group-based project work, we have oriented towards the PBL learning model. According to the literature [1, 2], the modern history of PBL began in the early 1970s at the medical school at McMaster University in Canada, and ever since, PBL has been adopted in various fields such as Teaching, Engineering and Management.

6.1 PBL Pedagogy

The PBL approach focuses education around a set of realistic, intrinsically motivating problems to fit the interests and needs of the learners. It acknowledges the possibility of prior knowledge held by the learner. Further knowledge is acquired on a 'need to know' basis, enabling the learner to diagnose one's own learning needs. Knowledge gained is fed back into the problem in an iterative loop, allowing the synthesis of topics and know-how [10]. When applied to the course setting, PBL should encourage students' active participation, and develop in them self-directed learning and problem-solving skills while they interact, discuss and share relevant knowledge and experience. More importantly, PBL revolves around a focal problem, group work, feedback, class discussion, skill development and final reporting. The instructor's role is to organize and pilot this cycle of activity, guiding, probing and supporting students' initiatives along the way so as to empower them to be responsible in their own learning.

6.2 PBL Activities

Students, on being presented with a problem or scenario, are made aware that initially they will not possess enough prior information to solve the problem at hand or to clarify the scenario immediately. These problems are often ill-structured, but devised according to concrete, open-ended situations. They are reminded that they must identify, locate, and use appropriate resources, and ask questions referred to as "learning issues" on the various aspects of the problem. These learning issues should help them realize what knowledge they require to construct a solution, and thus focus their learning efforts and establish a means for integrating the information they acquire. Often, they are encouraged to perceive themselves as managers of their own in terms of time, material resources, and the complexity of the problems that can be handled one at a time by the group. It is expected that the PBL students have to iterate through some relevant stages of activities: analysis, research, and reporting, with discussion and feedback from peers and the instructor at each stage.

- *Analysis.* Throughout this stage, students organize their ideas and prior knowledge related to the problem, and start defining its requirements. This helps them devise a specific statement of the problem. Meanwhile, they are encouraged to pose learning issues, defining what they know and what they do not know. This helps them assign responsibilities for research, eliciting and activating their existing knowledge as a crucial step in learning new information.

- *Research.* Throughout this stage, students collect necessary information on specific learning issues raised by the group. They may conduct library searches, seek sources on the Internet, collect data, and interview knowledgeable authorities. More importantly, students teach themselves as they research their learning issues. It is intended that when they come to realize the complexity and texture of the problem, they may often see that information is a means to the ends of managing problems effectively.

- *Reporting.* At this stage, students report their findings to the group. Individual students become "experts" and teach one another. Subsequently, their discussion may generate a possible solution, or new learning issues for the group to explore further. Final solutions are constructed, and the facilitator's feedback should help students clarify basic information, focus their investigations, and refine their problem-solving strategies, besides addressing whether the original learning issues were resolved and whether the students' understanding of the basic principles, information, and relationships is sufficiently deep and accurate.

6.3 PBL Teamwork Experience

It is important that PBL students are taught how to work in teams and positively experience the team process because the team skills they acquire are applicable throughout their future careers. The PBL team process requires each team composed of 3-5 students, to be assigned a supervisor (instructor) and a client if applicable. The client's role is to clarify the project, and to resolve ambiguities as they arise, whereas the supervisor's is to guide, motivate and provide feedback to the team. Also, one of the team members is designated the team leader for the duration of the project, whose role is to coordinate the team activities, and to ensure effective team communications. The leader also has to interface with the supervisor, arrange meetings with clients when necessary, and facilitate meeting through setting agendas, taking minutes, and allocating tasks. Each team member has to help set the team goals, accomplish tasks assigned, meet deadlines, attend team meetings and take a turn editing a document to be submitted at the end of each major stage of project development.

Meanwhile, PBL students are made aware of the difficulties in teamwork throughout the project period. These include setting realistic project goals, carefully allocating tasks to team members, managing time, and communicating and managing shared group documents. Teams have regular meetings to which they invite their supervisor, and in which they organize themselves to manage the project. Students are often reminded of setting appropriate agendas before meeting, assigning enough time to the agenda items during meeting, restating the decisions made at the meeting, and converting decisions into action items after meeting. They are also advised on clearly separating the social and work aspects in meetings, and assessing each meeting for doing it better next time. Moreover, it is suggested that teams plan their project around major deadlines of individuals in the team thereby acknowledging the other commitments team members may involve.

Deadlines represent the milestones set down for the PBL students to submit project documents and to receive evaluation. Each team member is assessed by their supervisor and their team peers. The supervisor's evaluation is based on what each team member adds to the meetings and what the instructor perceives each member's contributions to the team to be. The peers' evaluation is based on a confidential rating sheet, to be completed by each team member at the end of each major phase of the project. This rating sheet should include each team member's contribution for that phase with explanatory comments. And the overall project assessment is made up of the group grade and the individual grade. The former is the same for each group member and is based on the quality of the documents produced and the product developed. The individual component is based on the quality of the student's contribution to the documents and the product, their participation in group-meetings, their commitment to the team process, and their professional attitude developed.

7 Scenario-Based PBL Support

Imagine you have just attended the second lesson on PBL and group project work. And you realize that the PBL support available in the Web comprises both the learning and performance aspects. These are actually a series of strategies and Web-based solutions that use instructional design principles to improve students' work-based performance according to the real-life PBL activities. And you are invited to visit the PBL-specific Web site to register as a PBL-user. The registration process invites you to fill in a Web form including a simple questionnaire for teaming purpose. You are now allowed to enter the PBL-support environment with your PBL identifier and personal password returned after the registration.

And for exploratory purpose, you have just navigated to the PBL Web page for the Software Engineering course *SFTW 300 Software Psychology* (Figure 1). Here you are presented with a number of projects to express your preferences to join through filling in another Web form activated by clicking the link "Join a Team" in the same page. You can then find out which team and project have actually been associated with you by clicking the link "Identify Your Team" also in the same page. On knowing which project to engage, you could click the suitable PBL Space link, i.e., "S300F99P3" in this case, to navigate to the suitable PBL Space (Figure 2). The PBL Space is assigned for each PBL group for project management on the Web. It contains links to the project itself, the PBL Group (including its members' links), the PBL Client, and the PBL Supervisor. Each of such links is associated with a set of related links for information and support of the project. Among the numerous support links in the PBL Group, you can find the *Work Space* link, which leads to the "Group Work Space" (Figure 3) Web page. This page contains links to individual group members and to specific PBL support, as well as to the project interim progress. Clicking on the individual member's link (PWS) leads to the "Personal Work Space" (Figure 4), where each group member's progress in terms of PBL activities (analysis, research, reporting, implementation) is tracked.

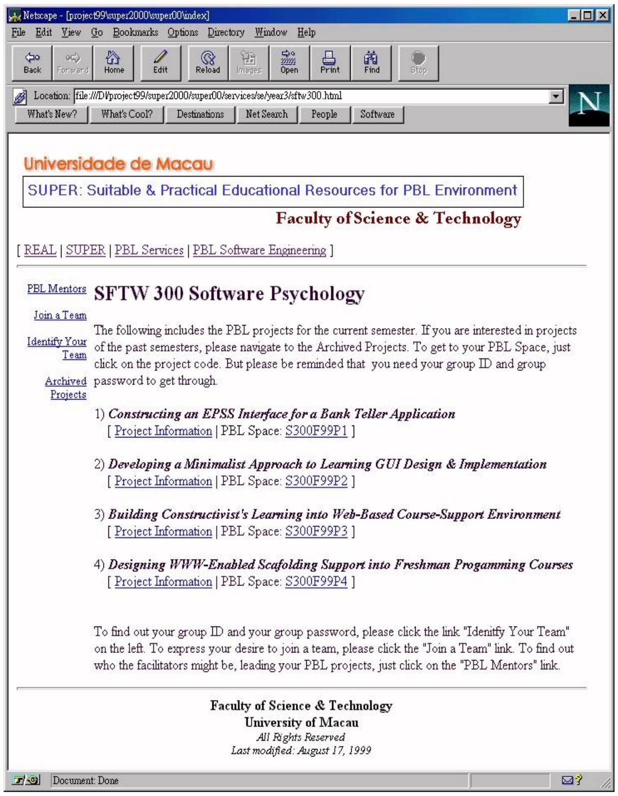

Figure 1: PBL Web Page for SFTW 300

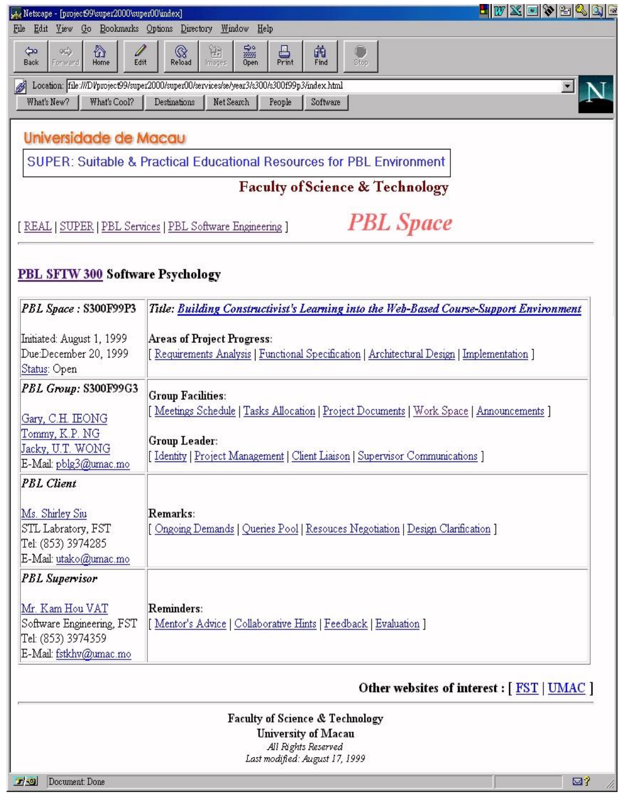

Figure 2: PBL Space for SFTW 300 Project

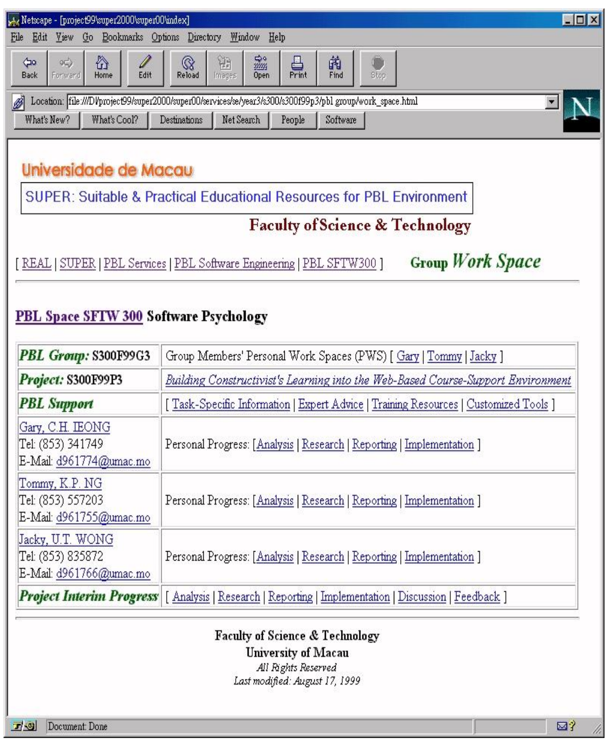

Figure 3: Group Work Space for a SFTW 300 Project

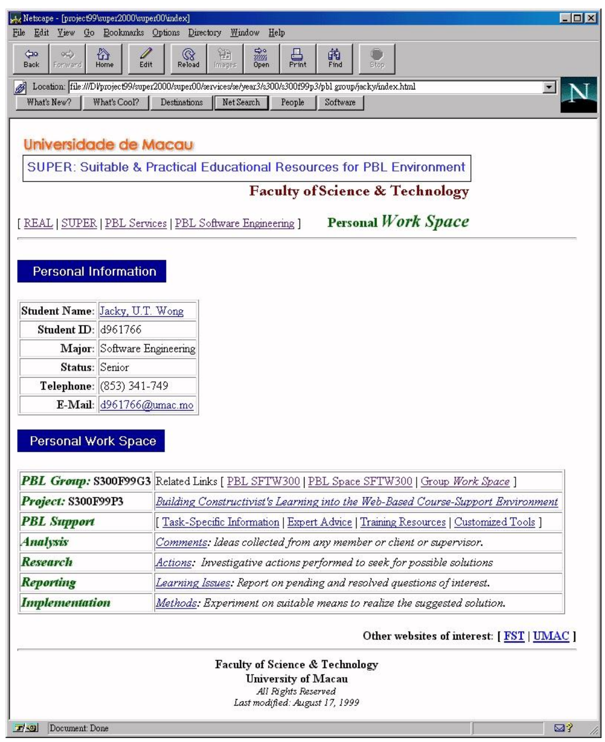

Figure 4: Personal Work Space for a SFTW 300 Project

8 Software Development

Our database-driven Web-based support environment has been developed as a series of distributed applications, by employing a mixture of object-orientation, client/server, and Internet (Web browsers, Web servers – HTML, HTTP, FTP) technologies, to deliver the desired support functionality. Such applications are largely event-driven because of the intensive graphical user interface (GUI) programming (e.g., handling the points and clicks) and/or because of the message exchanged between clients and servers over the Web. The specific types of individual Web applications constructed can be categorized into such classes as: a) static HTML-based, b) server-side (CGI-based) and c) client-side (Java-based or JavaScript-based). And the major steps followed to develop the distributed applications could be abstracted as follows:

a) *Analysis.* Establish users' requirements of what information are needed by whom and when, in terms of functionality, performance, security, operability, and management of the distributed applications. And develop an object model that shows conceptually how the information will be organized, accessed, manipulated, and presented in terms of objects.

b) *Architecture.* Partition the architecture concerns into: *data architecture*, determining what data sources (HTML, files, databases) will be needed, where they will be located, and how they will be accessed; *software architecture*, determining what will be written as CGI/Java code, what will be constructed as modules called by CGI/Java, where will the various objects/modules reside, and how they will be invoked (CORBA, RPC); *infrastructure architecture*, determining the servers where the home pages and the objects/modules will reside, the type of gateways that will be employed, the type of middleware that will be needed to invoke remote services and objects (CORBA, ActiveX, RPC, SQL), and the type of computing platforms (PC Windows, UNIX, Linux, Windows NT) used.

c) *Implementation and Deployment.* Build the HTML pages (including the Java-powered pages) by coding HTML or using filters that generate HTML from other data sources (e.g. Word documents). Then develop and test the software modules and objects. If necessary, purchase the appropriate infrastructure components. Fourth, test, install and deploy the system, followed by maintenance and the iterative re-design process.

9 Prototyping Process

The Web-based support in our online environment is developed incrementally through a user-driven iterative prototyping process, which involves our instructional designers, teachers, and students in the participatory development. This involves creating a series of function prototypes used to clarify the objectives of the system in light of design exploration between the designer and the users (teachers and students), so that the users gradually understand what can be achieved with the technology. Our knowledge of requirements, design and implementation may be incomplete in any one cycle; however, there has been progressive build-up of a structure, which will lead to the desirable system. Specifically, we have referred to the Dynamic Systems Development Method (DSDM) [12] for project guidance, which walks us through four main phases of the DSDM life cycle.

The *feasibility study* phase is to define the high level functional requirements of the environment, which refer to the educational support issues. This phase should produce an outline prototyping plan and establish the main non-functional requirements, such as the hardware and software to develop and deliver the system. The *functional prototype iterations* phase is to clarify the detailed requirements for the system. Its output includes a series of prototypes that demonstrate the main system functionality. These early visual prototypes are mainly used to clarify the system objectives between the designers and users. The *design prototype iterations* phase is to refine the functional prototype into a robust product after a more situated evaluation of system requirements. It involves satisfying all the non-functional requirements; i.e., producing a system that will work effectively on the target hardware in the organizational setting. It is understood that all the possible components of the system do not have to be developed in unison. Some may move on to the design and build phase while others are still at the functional clarification stage. The *implementation* phase involves placing the system in the user environment, carrying out any required training, reviewing the system and assessing further developments. The output should include a delivered system, user manuals/training, and project review document.

10 Conclusion

It is experienced that the conventional approach to education remains the instructivist one, in which knowledge is perceived to flow from experts to novices. This transmissive view of learning is most evident in the emphasis on lectures, in the use of textbooks to prescribe reading, and in the nature of tutorials and assessment methods. It assumes that the process of good teaching is one of simplification of the truth in order to reduce student confusion. Yet, this simplification could deny students the opportunity to apply their learning to dynamic situations. We question the transferability of the instructivist learning and ask how much of that which is assigned to academic learning ever gets applied to actual scenarios, when there is such a rapid surge in knowledge commonly associated with the birth of the "Information Age." This is a transference problem. Actually, the content product of learning is assuming a less important role relative to the process of learning as the life of information content shortens and the need for continual learning increases. In designing the Web-based support of our learner-centered environment, we have tried to reoriented towards a meaningful direction by reducing the obsession with knowledge reproduction. And PBL represents one such relief from the constructivist pedagogy. Greening [6] describes it as a vehicle for encouraging student ownership of the learning environment. There is an emphasis on contextualization of the learning scenario, providing a basis for later transference, and learning is accompanied by reflection as an important meta-cognitive exercise. Also, the implementation of PBL is done via group-based work, reflecting the constructivist focus on the value of negotiated meaning. Besides, it is unconfined by discipline boundaries, encouraging an integrative approach to learning, which is based on requirements of the problem as perceived by the learners themselves.

Undeniably, constructivism is a philosophy of learning that is having a major effect on the way that education is conducted today. In this paper, we have tried to spell out the working characteristics of constructivism [11], which have actively shaped the design of our Web-based support. These include: 1) Meaning is not transmitted. Instead, learning occurs as a process of adjustment of existing concepts. 2) Understanding is based on interaction among a complex weave of factors, such as the learners' goals and existing concepts, the content of the learning experience, the context where the learning occurs. 3) Puzzlement motivates learning. This sense of dissatisfaction emerges from experiences that threaten existing conceptual structures. 4) Social negotiation and viability are the principle forces involved in the evolution of knowledge. They ensure that learning is anchored both by the learning community and by the need to test constructions against reality. The effects of such testing are the adjustments in the structure of concepts held by the learner. So, one thing is evident: constructivist learning experiences can exert high cognitive demands on learners [8], and not all learners could respond well to the challenge. We believe the constructivist ideas assembled here make up what we might call pragmatic constructivism. Namely, constructivism could be viewed as a toolbox for problems of learning. If a particular approach does not solve the problem, try another. In keeping with this flexibility, active, social and creative learning can play out in rather different ways, depending on the circumstances. Although the term constructivism suggests a single philosophy and a unique potent method, there is not such thing as a one-size-fit-all. Rather, our suggestion is to look at constructivism like a Swiss knife with various blades for various needs. That is also the learner-centered philosophy behind our Web-based support for online education.

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